State of California
AIR RESOURCES BOARD

PRELIMINARY DRAFT STAFF REPORT

PROPOSED AMENDMENTS TO CALIFORNIA EXHAUST, EVAPORATIVE AND REFUELING EMISSION STANDARDS AND TEST PROCEDURES FOR PASSENGER CARS, LIGHT-DUTY TRUCKS AND MEDIUM-DUTY VEHICLES
"LEV II"

and

PROPOSED AMENDMENTS TO CALIFORNIA MOTOR VEHICLE CERTIFICATION, ASSEMBLY-LINE AND IN-USE TEST REQUIREMENTS
"CAP 2000"

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I. INTRODUCTION

Although significant strides have been made toward improving California's air quality, six major areas in the state continue to exceed the federal ambient ozone standards. These areas are: the South Coast Air Basin, San Diego Air Basin, San Joaquin Valley Air Basin, Southeast Desert Air Basin, and Ventura County. With the introduction of the new federal eight-hour ozone standard even more areas are likely to be designated as nonattainment. Ozone (created by the photochemical reaction of reactive organic gases (ROG) and oxides of nitrogen (NOx)) leads to harmful respiratory effects including lung damage, chest pain, coughing, and shortness of breath, especially affecting children and persons with compromised respiratory systems. Other environmental effects from ozone and its precursors include crop damage and secondary formation of particulate matter. It is clear that further reductions of ozone are necessary to reach our air quality goals in order to protect human health.

California's plan for achieving the federal ambient ozone standard is contained in the California State Implementation Plan (SIP) that was approved by the Board in 1994. A significant part of the SIP pertains to the control of mobile sources, which are estimated to account for approximately 60 percent of ozone precursors statewide. The SIP calls for new measures to cut ozone precursor emissions from mobile sources to half of what the emissions would be under existing regulations. SIP mobile source measure M2 (Improved Control Technologies for Light-Duty Vehicles), which calls for the adoption of technology-based emission control strategies for light-duty vehicles to be implemented beginning with the 2004 model year, is expected to achieve emission reductions of 25 tons per day (tpd) of ROG plus NOx by 2010 from light-duty vehicles in the South Coast Air Basin. In addition to Measure M2, the SIP recognizes that areas designated as extreme ozone nonattainment (the South Coast Air Basin) may need to rely on the development of additional technology measures as specified in Section 182(e)(5) of the Clean Air Act Amendments of 1990 in order to achieve required air quality goals. The SIP calls for additional emission reductions in the South Coast Air Basin of approximately 75 tpd ROG plus NOx (the inventory of these emissions is referred to as the "Black Box").[1]

The main purpose of this rulemaking, therefore, is to address the requirements of California's SIP Measure M2 and to introduce advanced technology measures to achieve additional emission reductions needed for the South Coast Air Basin. The proposed amendments would affect passenger cars, light-duty trucks and medium-duty vehicles and would include lower tailpipe standards, lower manufacturer fleet average non-methane organic gas (NMOG) values, a

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[1] The emission reduction estimates contained in this report pertain to the South Coast Air Basin (SoCAB) because it is the only nonattainment area in the United States designated as extreme and extra controls will be needed to bring this area into attainment. While the emission reduction strategies identified in this report target the SoCAB, the rest of the state will benefit from the strategies identified for this basin.

“zero” evaporative emission and refueling standard, revisions to the criteria for determination of zero-emission vehicle (ZEV) credits, and numerous technical modifications that would update the regulations and test procedures to account for developing technologies such as hybrid electric vehicles. Although staff will be proposing additional flexibility in determining the eligibility of a vehicle for receiving a ZEV credit, revisions to the 2003 and subsequent model year 10% ZEV requirement will not be considered in this rulemaking. Finally, staff will be proposing modifications to the Smog Index Label specifications to include the proposed new emission standards and modifications to the NMOG Test Procedures to reflect updates in laboratory procedures and instrumentation. Except for the evaporative amendments, these proposed amendments will be discussed in Part II of this Staff Report. The evaporative emission and refueling proposal will be discussed in Part III.

Another aspect of this rulemaking covers proposed amendments to the certification and in-use compliance requirements for motor vehicles. In 1995, the U.S. Environmental Protection Agency (U.S. EPA), ARB and the automobile manufacturers signed a Statement of Principles that states:

> “... the Signatories commit to working together to achieve regulatory streamlining of light-duty vehicle compliance programs, including reduction of process time and test complexity, with the goal of more optimal resources spent by both government and industry to better focus on in-use compliance with emission standards.”

Since then, staff has been working with EPA and the automobile industry to develop a streamlined motor vehicle certification process coupled with an enhanced in-use compliance program (called “Compliance Assurance Program” or “CAP 2000”). As part of the effort, California agreed to harmonize to the greatest extent possible with the federal programs in order to further reduce the regulatory burden on automobile manufacturers, while at the same time ensuring that stringency of the California programs is not reduced in any way. The amendments being proposed in this rulemaking are a result of this process and will be discussed in Part IV of this Staff Report.

II. PROPOSED AMENDMENTS TO CALIFORNIA'S LOW-EMISSION VEHICLE PROGRAM (LEV II)

A. BACKGROUND

In 1990, California adopted the most stringent exhaust regulations ever for the control of emissions from light- and medium-duty vehicles with its Low-Emission Vehicle (LEV) Program. Today's passenger cars and light-duty trucks are over 90% cleaner than when they were first regulated in the 1960s. This section provides an overview of the original LEV Program including vehicle weight classifications and passenger car, light-duty truck and medium-duty vehicle emission standards.

1. **Vehicle Classes and Exhaust Emission Standards.** There are currently seven vehicle classifications that fall under the LEV program:

passenger cars (PCs) (all weights);
light-duty trucks 0-3750 lbs. loaded vehicle weight (LVW)[2] (LDT1) and
    3751-5750 lbs. LVW (LDT2);
medium-duty vehicles 3751- 5750 lbs. test weight (TW) (MDV2),
    5751-8500 lbs. TW (MDV3),
    8501-10,000 lbs. TW (MDV4), and
    10,001-14,000 lbs. TW (MDV5).

The weight classifications for trucks were created in recognition of the larger load carrying capacity and more rigorous duty cycle of trucks that could lead to more severe emission deterioration. Testing of light-duty trucks and medium-duty vehicles also accounts for these differences in load carrying capacities. While LDTs are tested with an extra 300 pounds added to the weight of the vehicle, the weight at which a MDV is tested is higher because it is based on one-half of the payload of the vehicle (generally 1,000 lbs. or more) plus the curb weight. Because the payload of an MDV can vary even within the same model (e.g., a Ford F150 can have a payload ranging from 1390 to 2435 lbs.), the same vehicle platform can be certified as an LDT2 or MDV2. This split in vehicle categories can also happen between MDV2 and MDV3.

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[2] There are several classifications for vehicles based on weight. Curb weight is defined as the actual weight of the vehicle. Loaded vehicle weight (LVW) is defined as the curb weight of the vehicle plus 300 pounds. Gross vehicle weight rating (GVW) is the curb weight of the vehicle including the full payload. Test weight (TW), also known as adjusted loaded vehicle weight (ALVW), is the weight at which a medium-duty vehicle is tested and is defined as the average of a vehicle's curb weight and gross vehicle weight.

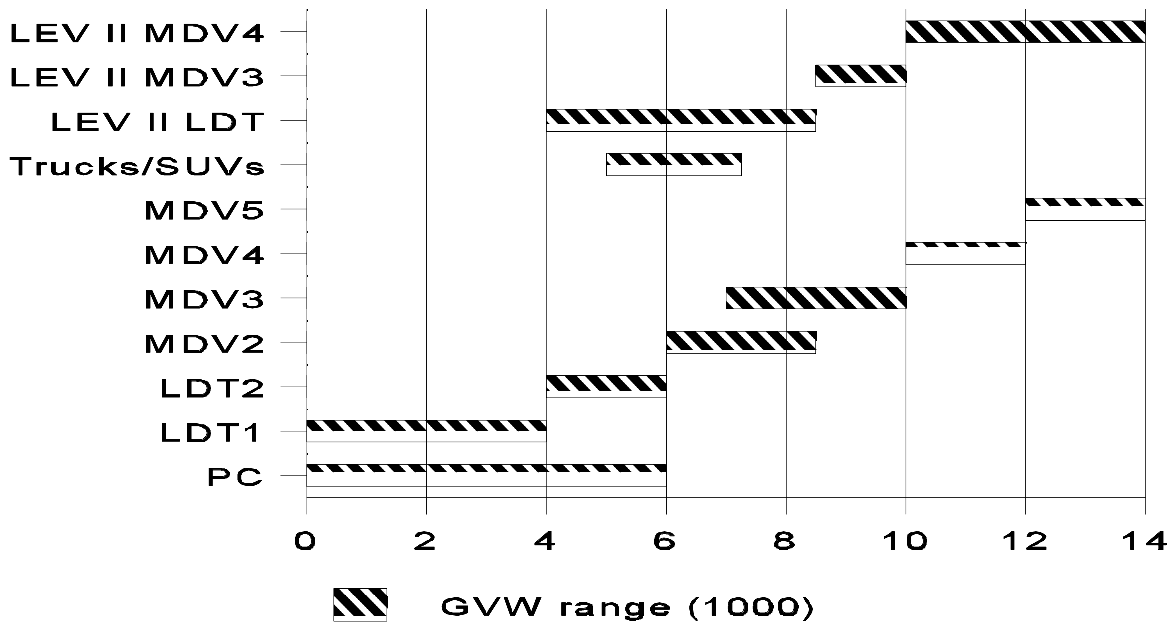

Figure 1 illustrates the overlap in these vehicle categories under the current LEV I program. This figure also includes the proposed LEV II vehicle classes that will be discussed later in this report.

Within each vehicle classification there are also several emission standards to which a vehicle may certify. In order of increasing stringency, these standards are: transitional low-emission vehicle (TLEV), low-emission vehicle (LEV), ultra-low-emission vehicle (ULEV) and super-ultra-low-emission vehicle (SULEV) and are set forth in Table II-1.

Table II-1

Current Exhaust Mass Emission Standards for TLEV, LEV, and ULEV Passenger Cars and Light-Duty Trucks and LEV, ULEV and SULEV Medium-Duty Vehicles

Vehicle Type	Mileage for Compliance	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)	Formaldehyde (mg/mi)	Diesel Particulate (g/mi)
All PCs; LDT1s (0-3750 lbs. LVW)	50,000	Tier 1	0.25	3.4	0.4	n/a	0.08
		TLEV	0.125	3.4	0.4	15	n/a
		LEV	0.075	3.4	0.2	15	n/a
		ULEV	0.040	1.7	0.2	8	n/a
LDT2s (3751-5750 lbs. LVW)	50,000	Tier 1	0.32	4.4	0.7	n/a	0.08
		TLEV	0.160	4.4	0.7	18	n/a
		LEV	0.100	4.4	0.4	18	n/a
		ULEV	0.050	2.2	0.4	9	n/a

Vehicle Type	Mileage for Compliance	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)	Formaldehyde (mg/mi)	Diesel Particulate (g/mi)
MDV2s (3751-5750 lbs. TW)	50,000	Tier 1	0.32	4.4	0.7	18	n/a
		LEV	0.160	4.4	0.4	18	n/a
		ULEV	0.100	4.4	0.4	9	n/a
		SULEV	0.050	2.2	0.2	9	n/a
MDV3s (5751-8500 lbs. TW)	50,000	Tier 1	0.39	5.0	1.1	22	n/a
		LEV	0.195	5.0	0.6	22	n/a
		ULEV	0.117	5.0	0.6	11	n/a
		SULEV	0.059	2.5	0.3	6	n/a
MDV4s 8501 -10,000 lbs. TW	50,000	Tier 1	0.46	5.5	1.3	28	n/a
		LEV	0.230	5.5	0.7	28	n/a
		ULEV	0.138	5.5	0.7	14	n/a
		SULEV	0.069	2.8	0.35	7	n/a
MDV5s 10,001-14,000 lbs. TW	50,000	Tier 1	0.60	7.0	2.0	36	n/a
		LEV	0.300	7.0	1.0	36	n/a
		ULEV	0.180	7.0	1.0	18	n/a
		SULEV	0.09	3.5	0.5	9	n/a

There are additional emission standards at 100,000 miles for passenger cars and light-duty trucks and 120,000 miles for medium-duty vehicles.

2. Phase-In Requirements. One of the flexibilities of the LEV Program is that a manufacturer may chose the standards to which each vehicle is certified provided the overall fleet meets the specified phase-in requirements. For passenger cars and light-duty trucks, the non-methane organic gas (NMOG) emissions averaged over a manufacturer's entire light-duty product line must meet the following values:

Table II-2
Fleet Average NMOG Requirements

Vehicle Category	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
PCs; LDTs 0-3750	0.250	0.231	0.225	0.202	0.157	0.113	0.073	0.070	0.068	0.062
LDTs 3751-5750	0.320	0.295	0.287	0.260	0.205	0.150	0.099	0.098	0.095	0.093

The only instance where a specified percentage is required is for zero-emission vehicles, where each large and intermediate volume manufacturer must produce 10% of its PC and LDT1 production volume as zero-emission vehicles beginning in 2003. The separate fleet average values for the heavier category of light-duty trucks reflects the higher emission standards applicable to these trucks and the lack of a separate ZEV requirement pertaining to these vehicles.

There are two types of medium-duty vehicles - those that are certified using the chassis dynamometer (the left column of Table II-3) and those certified using an engine dynamometer (the right column of Table II-3). Medium-duty vehicles have separate requirements based on a percent phase-in schedule because the numerous vehicle weight classifications make a fleet average requirement difficult to implement.

Table II-3
Medium-Duty Vehicle Phase-In Requirements

Model Year	Chassis Certified Vehicles (% Sales)			Engine Certified Vehicles (% Sales)		
	Tier 1	LEV	ULEV	Tier 1	LEV	ULEV
1998	73	25	2	100	0	0
1999	48	50	2	100	0	0
2000	23	75	2	100	0	0
2001	0	80	20	100	0	0
2002	0	70	30	0	100	0
2003	0	60	40	0	100	0
2004 +	0	60	40	0	0	100

B. SUMMARY OF PROPOSED LEV II AMENDMENTS

In order to meet the SIP commitments, staff considered the following strategies: restructuring the light-duty truck category to include larger trucks and sport utility vehicles (SUVs), lower tailpipe standards, lower fleet average requirements, increased durability requirements, a "zero" evaporative emission and refueling standard (discussed in Part III), and partial zero-emission vehicle credits for exceptionally clean vehicles. In addition staff will be proposing technical modifications to the hybrid electric vehicle test procedures to accommodate emerging hybrid technologies and modifications to the Smog Index label to incorporate the proposed lower exhaust and evaporative emission standards and updates to the NMOG Test Procedures to reflect updates in laboratory procedures and instrumentation. The following is a description of the staff proposal. A complete description of the regulatory amendments is contained in the appendices.

1. Proposed Restructuring of the Light-Duty Truck Category. In addition to increasing the stringency of the exhaust emission standards (to be discussed in B.2 below), staff is proposing a substantial restructuring of the light-duty truck category. The trucks and SUVs that would be affected by this rulemaking include light trucks such as the Toyota RAV4 and Ford Ranger; medium-light trucks such as the Jeep Grand Cherokee, Chevy Blazer, Ford Explorer, all mini-vans; and the heavier light trucks such as the Ford F150, Ford Expedition, Chevrolet Suburban and Dodge Ram 1500 trucks. Vehicles that are likely to remain in the proposed medium-duty vehicle category include the yet to be introduced Ford Excursion, Ford F250 and F350 Super-Duty trucks, Dodge Ram 2500 and 3500 trucks, the largest version of the Chevrolet Suburban and many full size vans.

When the light-duty truck (LDT) and medium-duty vehicle (MDV) categories were first established, the majority of vehicles in the MDV category were primarily used for work purposes (e.g., a Ford F150 was used by electricians, plumbers, painters, etc.). Because these work vehicles have a larger load carrying capacity and a potentially more rigorous duty cycle, separate and less stringent emission standards were developed that account for more severe emission deterioration. The high sales numbers of full size pick-up trucks, and the more recent introduction of extremely popular SUVs, however, has greatly altered the light- and medium-duty truck use patterns. Whereas these vehicles were traditionally used for work purposes, it is now very common for trucks and SUVs to be used primarily for personal transportation (i.e., as passenger cars). In addition, SUVs have been increasing in market share and now constitute almost 15% of the vehicle market. *Automotive News* (October 13, 1997) reports that the U.S. new vehicle market, "once dominated by cars, is approaching a car/light-duty truck split" with cars declining from 80% in 1980 to 54% in 1997. Light trucks (including SUVs) have increased from 20% in 1980 to almost 46% in 1997. This trend has a substantial impact on California's air quality because, although these vehicles are used as passenger cars, they are certified to the more lenient gram per mile (g/mi) emission standards designed for work trucks.

In determining the criteria for the new truck category, staff considered several options. The biggest obstacle in selecting an appropriate vehicle weight criterion is how to distinguish work trucks from trucks used primarily for personal transportation. Another important consideration is how to ensure that trucks used primarily for personal transportation would not be certified to the higher weight categories just to avoid more stringent truck standards. One option that staff considered involved differentiation based on type of axle (semi-floating vs. full floating axle) but this was not selected because almost all of the heavier SUVs are equipped with a full floating axle as standard equipment. Curb weight was also considered because it appeared to provide the least likely opportunity for manufacturers to slip vehicles into the higher weight categories that have more lenient standards. Consideration was also given to discriminating work trucks based on the number of wheels or trailer towing capacity. After considerable discussion with manufacturers, staff is proposing that the cutpoint be based on GVW and selected 8,500 lbs. GVW as the dividing point. Most pick-up trucks and SUVs have a curb weight less than 5,500 lbs. and a payload of approximately 1,000 lbs., so that most will fall below 8,500 lbs. GVW. It appears unlikely that manufacturers would unnecessarily add payload to trigger a numerically higher standard because of the negative impact on fuel economy, performance and cost. Staff will consider alternatives to the 8,500 lb. cutpoint to accommodate the heaviest light trucks if doing so is justified from a technological feasibility standpoint, and other adjustments could be made to ensure no loss of overall emission reductions.

At this time, though, staff is proposing that the light-duty truck category be restructured whereby the lightest weight category, 0-3750 lbs. LVW would remain the same because the ZEV requirement affects only this truck class, trucks between 3751 lbs. LVW and 8,500 lbs. GVW would be combined in a new LDT2 truck category and trucks over 8,500 lbs. GVW would remain in the medium-duty vehicle category. Thus, the new LDT2 light-duty truck category would include the current light-duty truck 3751-5750 lb. LVW classification and all trucks currently classified as medium-duty vehicles under 8,500 lbs. GVW.

2. Proposed Exhaust Emission Standards. In this rulemaking staff is proposing new "LEV II" standards for light- and medium-duty vehicles that represent a significant strengthening of the preexisting LEV standards. First, as mentioned above, staff is proposing that light-duty trucks that fall into the new LDT2 truck category from 3751 lbs. LVW to 8,500 lbs. GVW meet the same standards applicable to passenger cars. Second, staff is proposing a 0.05 g/mi NOx standard for light-duty LEVs and ULEVs and lowering overall standards for medium-duty vehicles over 8,500 lbs. GVW. Third, staff is proposing that the full useful life for both passenger cars and light-duty trucks be increased from 100,000 miles to 120,000 miles. Fourth, staff is proposing the introduction of a new emission standard -- Super-Ultra-Low-Emission Vehicle or "SULEV," for passenger cars and light-duty trucks. Fifth, staff is proposing a reduction in the light-duty vehicle particulate matter standards to 0.04 g/mi for TLEVs and to 0.01 g/mi for LEVs, ULEVs and SULEVs. Finally, staff is proposing an optional extension of the full useful life to150,000 miles while still meeting the same numerical 120,000 mile standards for which commensurate additional fleet average NMOG credit would be provided. Table II-4 below sets forth the proposed LEV II standards; a discussion of each aspect of the proposal follows:

Table II-4

Exhaust Mass Emission Standards for New 2001 and Subsequent Model TLEVs, LEVs, ULEVs, and SULEVs in the Passenger Car, Light-Duty Truck and Medium-Duty Vehicle Classes

Vehicle Type	Mileage for Compliance	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)	Formaldehyde (mg/mi)	Diesel Particulate[1] (g/mi)
All PCs; LDTs <8,500 lbs. GVW Vehicles in this category are tested at their loaded vehicle weight	50,000	TLEV	0.125	3.4	0.4	15	n/a
		LEV	0.075	3.4	0.05	15	n/a
		ULEV	0.040	1.7	0.05	8	n/a
	120,000	TLEV	0.156	4.2	0.6	18	0.04
		LEV	0.090	4.2	0.07	18	0.01
		ULEV	0.055	2.1	0.07	11	0.01

Vehicle Type	Mileage for Complianc e	Vehicle Emissio n Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)	Formaldehyd e (mg/mi)	Diesel Particulate[1] (g/mi)
		SULEV	0.010	1.0	0.02	4	0.01

Vehicle Type	Mileage for Compliance	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)	Formaldehyde (mg/mi)	Diesel Particulate[1] (g/mi)
	150,000 (Optional)	TLEV	0.156	4.2	0.6	18	0.04
		LEV	0.090	4.2	0.07	18	0.01
		ULEV	0.055	2.1	0.07	11	0.01
		SULEV[3]	0.010	1.0	0.02	4	0.01
MDVs 8500-10,000 lbs. GVWR Vehicles in this category are tested at their adjusted loaded vehicle weight	50,000	LEV	~~0.195~~ 0.160	~~5.0~~ 4.4	~~0.6~~ 0.1	22	n/a
		ULEV	~~0.117~~ 0.100	~~5.0~~ 4.4	~~0.6~~ 0.1	11	n/a
		SULEV	~~0.059~~ 0.050	~~2.5~~ 2.2	~~0.3~~ 0.05	6	n/a
	120,000	LEV	~~0.280~~ 0.230	~~7.3~~ 6.4	~~0.9~~ 0.2	32	0.12
		ULEV	~~0.167~~ 0.143	~~7.3~~ 6.4	~~0.9~~ 0.2	16	0.06
		SULEV	~~0.084~~ 0.072	~~3.7~~ 3.2	~~0.45~~ 0.07	8	0.06
	150,000	LEV	0.230	6.4	0.2	32	0.12
		ULEV	0.143	6.4	0.2	16	0.06
		SULEV	0.072	3.2	0.07	8	0.06
MDVs 10,001-14,000 lbs. GVWR Vehicles in this category are tested at their loaded vehicle weight	50,000	LEV	~~0.230~~ 0.195	~~5.5~~ 5.0	~~0.7~~ 0.3	28	n/a
		ULEV	~~0.138~~ 0.117	~~5.5~~ 5.0	~~0.7~~ 0.3	14	n/a
		SULEV	~~0.069~~ 0.059	~~2.8~~ 2.5	~~0.35~~ 0.2	7	n/a
	120,000	LEV	~~0.330~~ 0.280	~~8.1~~ 7.3	~~1.0~~ 0.5	40	0.12
		ULEV	~~0.197~~ 0.167	~~8.1~~ 7.3	~~1.0~~ 0.5	21	0.06
		SULEV	~~0.100~~ 0.084	~~4.1~~ 3.7	~~0.5~~ 0.2	10	0.06

(a) **Proposed passenger car and light-duty truck standards.** Initially, staff based the lower LEV and ULEV standards on recent certification data that suggest light-duty trucks would be able to meet passenger car standards and that both passenger cars and light-duty trucks would be able to meet a 0.05 g/mi NOx standard. To confirm this, staff is conducting a test program to demonstrate the feasibility of these standards. A discussion of the test results to date and technological feasibility of this proposal is contained in Section C below.

In determining the standards that would apply to the new LDT2 truck category, staff considered the fact that while the truck standards are currently differentiated into separate weight classes to account for their load carrying capacity, the same is not true for passenger car standards. Although passenger cars can be used for towing or carrying moderate loads, the heavier, larger PCs are required to meet the same emission standards as the smallest models because all vehicles are primarily used for personal transportation. With the substantial increase in the number of pick-up trucks, SUVs and minivans being primarily used as passenger cars, staff believes that they should also be required to meet passenger car standards. While automobile manufacturers seem to acknowledge that it is possible to achieve passenger car emission levels for trucks at low mileage, they contend that maintaining low levels for the useful life of the truck is not possible. However, recent advancements in emission control technologies should enable the low emission levels to be maintained for the useful life of these vehicles. The use of advanced durability catalysts, in particular, would make the vehicles less susceptible to deterioration from load carrying or towing conditions.

Staff is proposing to keep the TLEV standard at current levels in order to provide a feasible standard for the heavier light trucks, in order accommodate very active emission reduction efforts on both gasoline and diesel vehicles in this category. By keeping the TLEV option, manufacturers would have a standard with which to certify until technological development can be brought to passenger car levels. Staff is also requiring that all vehicles (including diesel) under 8,500 lbs. GVW continue to certify to the light-duty truck chassis standards. Under current regulations, medium-duty LEV and ULEV diesel trucks over 8,500 lbs. GVW have the option to certify as heavy-duty engines meeting the federal heavy-duty diesel engine standards rather than the potentially more stringent light- or medium-duty vehicle chassis standards. As the number of pickup trucks and SUVs increases, manufacturers may turn to diesel trucks to offset the reduced fuel economy of gasoline trucks and SUVs in order to meet federal fuel economy requirements. While certifying diesels to the LEV and ULEV standards would be a challenge, some may be able to certify to the TLEV standards. It is important to note, however, that the declining fleet average would likely preclude large numbers of trucks from being certified as TLEVs but this allowance would give diesel emission control technology additional time to improve. Diesel trucks over 8,500 lbs. GVW would continue to have the option to certify to the heavy-duty engine standards. Staff will be investigating other compliance options in the passenger car and light-duty truck categories to provide additional flexibility to manufacturers in meeting these standards.

(b) **Proposed medium-duty vehicle emission standards**. Although the new light truck category would include the vast majority of light-duty trucks, there are some SUVs and trucks that would fall into the new medium-duty category (e.g., Ford Excursion and some Chevrolet Suburbans). In order to ensure the same level of stringency while still taking into account the potentially more rigorous duty cycle of vehicles in this category, staff is proposing new standards that will be substantially equivalent in stringency to the light-truck standards but numerically higher. (See Table II-4 for a list of the proposed standards.) One of the chief differences between the light-duty truck (LDT2) category and the MDV standards is how the vehicles are tested. Light-duty trucks are tested with 300 lbs. added to the vehicle while medium-duty vehicles are tested with half their payload (usually about 1,000 to 1,500 lbs.) added to the vehicle. This adds stringency to the standard because of the heavier test weight. In order to account for this difference, staff is proposing numerically higher emission standards that are essentially equivalent in stringency to the standards for light-duty trucks. See Section C. below for a discussion of the expected technologies that would be used to meet these new standards.

(c) **Proposed extension of useful life to 120,000 miles**. Current data on vehicle miles traveled indicate that, on average, passenger cars are driven 122,000 miles, light-duty trucks 110,000 miles, and medium-duty vehicles 118,000 miles during their first ten years of life. In addition, emission control systems have become more robust over the last several years as manufacturers strive to meet 100,000 mile low-emission standards and on-board diagnostic requirements. This trend coupled with the convergence of mileage accumulation among these groups suggests adoption of an updated, uniform useful life criterion. Accordingly, staff is proposing that, for passenger cars and light-duty trucks, the full useful life be defined as 10 years and 120,000 miles, whichever occurs first. The time constraint for medium-duty vehicles would be aligned with that for passenger cars and light-duty trucks at 10 years and the mileage would remain the same at 120,000 miles.

(d) **Proposed SULEV Standard**. Staff is proposing creation of a new light-duty SULEV standard because recent technology developments indicate that gasoline, alternative fuel and hybrid electric vehicles could potentially reach emission levels significantly lower than the ULEV standard. In October, 1997, Honda announced that an advanced prototype gasoline Accord could achieve exhaust emission levels near zero. Honda has also presented data for a compressed natural gas vehicle with emission levels at one tenth of current 50,000 mile ULEV requirements over its full useful life. This vehicle is currently available for sale in California. In addition, many automobile manufacturers have indicated that they are seriously considering plans to mass-produce hybrid electric vehicles (HEVs) and some manufacturers have unveiled their close-to-production prototypes. Toyota is currently selling an HEV equipped with both an electric motor and a 1.5 liter gasoline engine in Japan. Given the potential for some hybrid designs to utilize constant speed auxiliary power unit operation and preheated catalytic converters, achieving emissions at the proposed SULEV emission level should be possible. Thus, staff is proposing the creation of a new emission category, SULEV, for these very clean vehicles that manufacturers could choose to certify to. The proposed emission values represent staff's estimate of levels that can be achieved cost effectively using the best available control technology, though not necessarily the most exotic, using a variety of fuels including Phase 2 gasoline. Sales of vehicles certified to the SULEV standard would help manufacturers reduce their fleet average NMOG values.

(e) **Proposed particulate matter standards**. The effects of particulate matter (PM) on health and visibility are of increasing concern, especially PM emissions 2.5 microns or less in size ($PM_{2.5}$). In response to these concerns, the U.S. EPA has promulgated new ambient air quality standards for $PM_{2.5}$. Since mobile source emissions are a major contributor to $PM_{2.5}$, staff is proposing a full useful life LEV, ULEV and SULEV PM standard of 0.010 g/mi for light-duty diesel vehicles and trucks less than 8,500 lbs. GVW. Diesel vehicles certifying to TLEV standards would be required to meet a full useful life PM standard of 0.04 g/mi. These standards are intended to provide an upper limit on PM emissions from vehicles used in large measure for personal transportation.

The data for light-duty diesel vehicles suggest that significantly more development is needed for these vehicles to meet a 0.010 g/mi PM standard. Recent certification data from two light-duty diesel vehicles shows PM emissions of 0.05 g/mi and NOx emission of 0.7 g/mi. Given the low NOx standards being proposed for LEV II and the difficulty associated with simultaneously achieving both low NOx and PM emissions from diesel engines, it is unclear whether diesel vehicles will be able to achieve a 0.01 g/mi LEV or ULEV PM standard in the foreseeable future. However, with further improvements to engine controls and the development of lean-NOx catalyst technology, light-duty diesels may be able to meet the 0.04 g/mi TLEV PM standard. Use of particulate traps also remains an option.

For gasoline vehicles, the data suggest that properly functioning vehicles emit PM at levels well below 0.010 g/mi. One recent study by the Environmental Research Consortium measured an average PM exhaust level of 0.0006 g/mi on a fleet of six low mileage passenger cars tested on California Phase 2 gasoline, an average of 0.0008 g/mi PM on a group of three high mileage passenger cars tested on Phase 2 gasoline, an average of 0.001 g/mi on a fleet of low mileage light-duty trucks tested on Indolene and Phase 2 gasoline, and an average of 0.002 g/mi on three other high mileage trucks tested on Phase 2 gasoline. Based on this data, staff is proposing to maintain the exemption for gasoline vehicles from the PM standards. Staff is soliciting comments on whether extending a PM requirement to any alternative fuel is warranted.

(f) **Optional 150,000 mile Certification Standard.** The ARB's Emission Inventory shows that approximately 20 percent of all vehicle miles traveled are from vehicles that have accumulated between 100,000 and 150,000 miles. Emissions from these vehicles represent a significant portion of the emission inventory. In order to promote vehicles that are durable even after their defined useful life (120,000 miles), staff is proposing an optional 150,000 mile certification standard equal to the applicable 120,000 mile standard. Manufacturers that certify to this optional standard would need to meet the following enhanced requirements:

i) The vehicle would be certified to the applicable 120,000 mile standard at 150,000 miles;

ii) The emission warranty requirements for high cost warranty parts would be increased from 7-years/70,000 miles to 8-years/100,000 miles; and

iii) High mileage in-use compliance testing requirements would be extended from 75,000 miles to 105,000 miles.

For certifying to this optional standard, manufacturers would receive additional NMOG credits towards compliance with the fleet average requirements. Specifically, under this proposal, the vehicles certifying to the optional 150K standard will use an NMOG value that is 85% of the 50,000 mile standard for the purpose of calculating the fleet average requirement.

Table II-4
150,000 Mile Fleet Average NMOG Values

Model Year	Emission Category	NMOG Emission Standard Value	
		All PCs; LDTs 0-3750 lbs. LVW	LDTs 3751 lbs. LVW - 8500 lbs. GVW
2004 and subsequent model year vehicles certified to the optional 150,000 mile "LEV II" standards for PCs and LDTs	TLEVs	0.11	0.11
	LEVs	0.06	0.06
	ULEVs	0.03	0.03

This value was calculated based on the following assumptions. Staff estimated the benefit attributable to vehicles that are certified to the optional standard to be approximately the difference between applicable 120,000 mile standard and the OBD II malfunction indicator light threshold. Staff assumed that after a vehicle exceeds its 120,000 mile useful life, the on-board diagnostic system would be the primary means of alerting the driver if emissions exceed 1.5 times the 120,000 mile-standard and that for vehicles certifying to the optional 150K standard, it is expected the vehicle would still be at or below the 120,000 mile-standard even after exceeding 120,000 miles of operation in order to comply with the standards. Mathematically, the benefit of a vehicle that is certified to the optional standard relative to a vehicle that is not, is as follows:

NMOG benefit (in grams) = (OBD II threshold - 120,000 mile standard) x (30,000 miles)
= [(1.5 x 120,000 mile std.) - (120,000 mile std.)] x 30,000
= 0.5 x (120,000 mile std.) x 30,000

The above NMOG benefit that is accrued from extending compliance from 120,000 miles to 150,000 miles is then spread over the full useful life to determine the amount by which the 50,000 mile standard should be lowered to characterize a vehicle certified to the optional 150,000 mile standard as follows:

Adjustment to the 50,000 mile standard = NMOG benefit (in grams) ÷ 120,000 miles
= [0.5 x 120,000 mile std. x 30,000] ÷ 120,000
= (120,000 mile std.) ÷ 8

Using this approach, staff estimated the adjustment to the 50,000 mile std. for the light-duty TLEV, LEV and ULEV standards. In each case, the adjustment was greater than or equal to 0.15 times the 50,000 mile standard. Therefore, staff is proposing that the adjustment for all vehicles certifying to this optional standard be set at 0.15 times the 50,000 mile standard.

Consequently, vehicles certifying to the optional 150K standard will be counted as being certified to (in grams/mile):

= 50,000 mile std. - (0.15 x 50,000 mile std.)
= 0.85 x 50,000 mile standard

for the purpose of calculating the fleet average requirement. Choosing this option will result in a manufacturer achieving a lower NMOG fleet average, and thus provide an incentive to increase the durability of the vehicle.

(g) **Updates to the NMOG Test Procedures**. The purpose of the modifications being proposed to the NMOG Test Procedures is to update instrumentation and suggested operating parameters to provide valid data. Although, the suggested modifications were not available at the time of publication, staff has been working with industry to develop the amendments which will be available at the workshop.

(h) In addition to the above, staff will be proposing several detailed technical amendments to the standards. A complete description of these amendments is described in the appendices. Some of the more pertinent proposed modifications include the following: Tier 1 standards will no longer apply after the 2002 model year for MDVs and 2003 for light-duty vehicles; the 50°F multiplier for SULEVs would be 2.0 (the same as for LEVs and ULEVs); the SFTP standard for SULEVs will be the same as for LEVs and ULEVs; and cold temperature carbon monoxide standard for SULEVs would also be 10.0 g/mi.

3. Proposed Phase-In Requirements.

(a) Passenger Cars and Light-Duty Trucks. One of the most important features of the current LEV Program is the ability of manufacturers to chose the standards to which vehicles are certified as long as the emissions of their entire product line meet a fleet average requirement. This provides flexibility to manufacturers because they can adapt their phase-in to better fit their product development schedules, as long as the fleet average is at or below the required levels. The current LEV I fleet average requirements decline through the 2003 model year after which they remain constant. Under LEV II, the fleet average requirement would continue to decline from 2004 through the 2010 model year. Although the vehicle emission standards for LDT1s and LDT2s are identical, the two categories are not combined into one fleet average requirement because the percentage ZEV requirement is based on the production volume of PCs and LDT1s. Table II-5 sets forth the proposed fleet average requirements for passenger cars/light-duty trucks (LDT1) and light-duty trucks (LDT2).

Table II-6

FLEET AVERAGE NMOG EXHAUST MASS EMISSION REQUIREMENTS FOR LIGHT-DUTY VEHICLE WEIGHT CLASSES (50,000 mile Durability Vehicle Basis)		
Model Year	Fleet Average NMOG (grams per mile)	
	All PCs; LDTs 0-3750 lbs. LVW	LDTs 3751-7300 lbs. LVW
2004	0.053	0.085
2005	0.049	0.076
2006	0.046	0.062
2007	0.043	0.055
2008	0.040	0.050
2009	0.038	0.047
2010+	0.035	0.043

The fleet average requirement for trucks in the new LDT2 truck category is slightly higher than those for passenger cars in order to provide a longer phase-in period for ULEVs and SULEVs. This would give manufacturers more time to adapt their most capable passenger car emission control technology to trucks in the new category that must achieve greater emission reductions because their emission levels are currently much higher than passenger cars. In addition, the truck fleet average is higher because it does not include a ZEV requirement (the passenger car fleet average requirement includes zero-emission vehicles, which automatically lowers a manufacturer's fleet average because they are counted as zero in the fleet average equation.)

Although manufacturers choose their own implementation schedule, the following is a possible phase-in scenario that staff judged to be feasible in the 2004-2010 time frame (and was used to develop the fleet average values).

Table II-7
One Possible Percentage Implementation Rate for
Passenger Cars and, Light-Duty Trucks 0-3751 lbs. LVW

Model Year	TLEV	LEV	ULEV	SULEV	ZEV
2004	2	48	35	5	10
2005	2	40	38	10	10
2006	2	35	41	12	10

Model Year	TLEV	LEV	ULEV	SULEV	ZEV
2007	1	30	44	15	10
2008	1	25	44	20	10
2009	1	20	49	20	10
2010	1	15	49	25	10

Table II-8
One Possible Percentage Implementation Rate for
Light-Duty Trucks 3751-7300 lbs. LVW

Model Year	TLEV	LEV	ULEV	SULEV	ZEV
2004	19	81	0	0	0
2005	16	63	21	0	0
2006	8	48	38	6	0
2007	2	43	50	5	0
2008	1	35	54	10	0
2009	1	25	64	10	0
2010	1	20	64	15	0

In order to provide the greatest flexibility possible, manufacturers would have the option of certifying a portion of their fleet to the current LEV standards as well as to the LEV II standards prior to the 2007 model year. Manufacturers would also be allowed to accrue debits for these first three years to allow them more flexibility in developing their product plans. By 2007, however, the current LEV standards would no longer apply and all deficits would need to be made up by the end of each model year.

(b) Medium-Duty Vehicles. The current regulations require that manufacturers must produce 60% of their medium-duty fleet as LEVs and 40% as ULEVs by the 2004 model year. Staff is proposing that the percent requirements be amended to required 40% LEVs and 60% ULEVs by the 2004 model year. These percentages apply to medium-duty vehicles certified to either the LEV I standards or the LEV II standards depending on a manufacturer's production schedule; however, Tier 1 MDVs can no longer be certified after the 2002 model year and the LEV I medium-duty LEVs and ULEVs can no longer be certified after the 2006 model year.

4. Partial ZEV Allowance Proposal to provide the flexibility to use multiple qualifying technologies to meet ZEV requirements.

(a) Background. When ARB adopted the original LEV program in 1990, the ZEV requirements were written to be technology neutral, that is, any technology could be used as long as it had zero vehicle emissions. However, battery-powered electric vehicles were considered the only technology available to meet the ZEV requirements in the near-term. In the eight years since the original program was adopted, a plethora of new, advanced technologies have been developed. Many of these technologies are capable of achieving extremely low levels of emissions on the order of the power plant emissions that occur from charging battery-powered electric vehicles, and some demonstrate other ZEV-like characteristics such as inherent durability and partial zero-emission range.

As a result of these new vehicle technologies, ARB staff is proposing additional flexibility in the ZEV program to broaden the scope of vehicles that could qualify for meeting some portion of the ZEV requirement. Manufacturers would decide which mix of vehicles to use to meet the 10% ZEV requirement with the exception that large-volume manufacturers would have to meet at least 40% of the requirement using true ZEVs. The applicable ZEV allowance for each vehicle type would be determined based on a set of criteria designed to identify and reward ZEV-like characteristics in a variety of advanced-technology vehicles. Revisions to the 2003 and subsequent model year 10% ZEV requirement will not, however, be considered in this rulemaking.

ZEVs are the "Gold Standard." Battery-powered electric vehicles and other ZEVs such as hydrogen fuel cell vehicles hold distinct air quality advantages over technologies that utilize a conventional fuel such as gasoline in a combustion engine. These advantages include 1) extremely low fuel-cycle emissions in California and 2) inherent emission durability. High volatility liquid fuels such as gasoline are responsible for significant fuel cycle emissions, i.e., emissions that occur upstream from the vehicle due to production, transportation, and vehicle fueling. Vehicles with combustion engines inevitably will exhibit increased emission levels as the vehicle ages. They are also subject to becoming gross polluters if critical emission control systems fail in-use. Although new vehicles have more durable emission control systems and on-board diagnostics systems that are effective in alerting owners to emission-related problems, owners may not respond to failure signals promptly. California's inspection and maintenance program will not capture vehicles that are operated without being registered and repair cost limits may permit continued operation of some high-emitters. For these reasons, staff considers vehicles that have no components with the potential to produce emissions, i.e. true ZEVs, to be the "gold standard" of even the cleanest, most advanced new technologies.

California Needs ZEVs To Meet Long-Term Air Quality Goals. The commercialization of ZEVs is critical to the long-term success of California's clean air program. Even with the full implementation of the proposed LEV II program, emissions from light-duty vehicles would still represent a significant portion of total emissions in the South Coast Air Basin.

Achieving the new air quality standards for particulate matter, not to mention the state ozone standard, will require further reductions. Taking into account the anticipated growth in the number of light-duty vehicles and the number of miles they travel each day, it is clear that in order to achieve these goals we need to essentially eliminate emissions related to vehicle deterioration and fuel use from a significant portion of the light-duty vehicle fleet. ZEVs can accomplish this goal.

The ZEV Program has Resulted in Many Success Stories. The ZEV requirements have been instrumental in promoting battery and vehicle research and development. As a result, a wide variety of battery-powered electric vehicles are now available to fleets and the general public. No less important, the program has also been successful in spawning a large variety of extremely low-emission vehicle technologies, many of which may not have gained significant attention without the ARB's ZEV requirements. Many of these technologies have at least some qualities inherent to ZEVs, such as extremely low emissions and extended durability, partial all-electric range or the use of an inherently durable non-combustion engine. The ARB staff believes it is good public policy to encourage these advanced technologies.

Table II-9
Comparison of ZEVs with Advanced Technology Vehicles

Advanced Technologies with Extremely Low-Emission or Zero-Emission Capability	Qualities in Common with ZEVs
Gasoline SULEV	Emissions comparable to EV-related power plant emissions and extended durability
Compressed Natural Gas SULEV	same as above plus very low fuel-cycle emissions
HEV with significant all-electric range	partial zero-emission range
Methanol reformer fuel-cell vehicle[1]	extremely low emissions
Direct methanol fuel-cell vehicle[1]	extremely low emissions
Stored hydrogen fuel-cell vehicle[1]	ZEV
Battery-powered electric vehicle	ZEV

[1]Due to their inherent efficiency of operation, fuel cell vehicles can also result in reduced emissions of carbon dioxide, a greenhouse gas.

Benefits of the Proposal. Staff believes this modified approach to counting vehicles toward the ZEV requirements would promote the continued development and commercialization of high-performance battery-powered electric and zero-emitting fuel cell vehicles while encouraging advanced technology vehicles with the potential for extremely low-emission performance. Technologies that best accomplish ARB's goal of achieving inherent durability and essentially zero vehicle and fuel-related emissions would receive the highest ZEV allowance. A manufacturer would be able to decide which mix of vehicles makes the most technological and economic sense based on its own strengths in each area. Further, under this proposal true ZEVs with at least 100 miles driving range would receive multiple ZEV credits to ensure steady market introduction in the early years when battery costs will be high. Staff believes this flexible approach would result in the commercialization of a broad range of new, advanced technologies, all of which would be valuable in meeting California's air quality goals. However, in order to ensure the continued development of zero-emission technologies, staff is proposing that a large-volume manufacturer be required to meet at least 40 percent of the ZEV requirement with true ZEVs.

(b) The Proposal. The process of calculating ZEV allowances for candidate vehicles consists of assigning basic "allowances" consisting of a baseline allowance, a zero-emission VMT allowance, and a low fuel-cycle emission allowance.

(1) Baseline ZEV allowance requirements. In order for a vehicle to receive any ZEV allowance, a vehicle would need to satisfy the requirements for receiving the "baseline ZEV allowance." To receive this allowance, the first requirement would be for the vehicle to at least meet the SULEV standard (emissions from vehicles in this category are close to emissions from powerplants associated with recharging electric vehicles) at 150,000 miles and also satisfy applicable second generation on-board diagnostics requirements (OBD II) and zero-evaporative emission requirements. It is important to note that while the SULEV standard is a 120,000 mile requirement, vehicles that qualify for ZEV credit would need to meet the SULEV standard for 150,000 miles. The vehicle manufacturer would also need to provide a 150,000 mile emission warranty such that all malfunctions identified by the vehicle's OBD II system would be repaired under warranty for a period of 15-years or 150,000 miles, whichever occurs first. The ARB believes that these conditions are necessary to ensure that vehicles receiving credit for near zero emissions are able to maintain them throughout the life of the vehicle. Vehicles meeting the above requirements would receive a 0.2 baseline ZEV allowance.

(2) Zero-emission VMT allowance. An additional allowance is provided based on the potential for realizing zero-emission vehicle miles traveled (VMT) (e.g. capable of some all-electric operation traceable to energy from off-vehicle charging), up to a maximum of 0.6. On the other hand if a vehicle does not have any zero-emission VMT potential but is equipped with advanced ZEV componentry, then the vehicle may qualify to earn an additional 0.1 ZEV allowance.

(i) Allowance for vehicles with significant zero-emission VMT potential. Many clean technologies, including some fuel-cell vehicles and hybrid electric vehicles, have the potential for zero emissions associated with some portion of the VMT. Under this proposal, such vehicles would receive a zero-emission VMT allowance, proportional to the estimated zero-emission VMT potential as a percent of total VMT which is the zero-emission VMT factor. To receive this credit, a manufacturer would need to provide an estimate of the likely zero-emission VMT potential of their particular vehicle design based on actual in-use data, an engineering evaluation of the vehicle's operational strategy and any other relevant information to validate the estimate. Upon review and approval of the manufacturer's estimate, this would be used by the Executive Officer to further calculate a zero-emission VMT allowance based on the following equation:

zero-emission VMT allowance = 0.6 x zero-emission VMT factor

The methodology to calculate the zero-emission VMT factor is described below.

Zero-emission VMT factor. For vehicles with significant city all-electric range (AER) capability such as some hybrid electric vehicle designs and others, the zero-emission VMT potential is estimated according to the following equation:

zero-emission VMT factor =	0.0	For city AER < 20 miles
	(30 + (0.5 x city AER))/80	For 20<=city AER <=100 miles
	1.0	For city AER > 100 miles

This equation is based on a 1990 Department of Transportation report showing cumulative VMT as a function of trip length for the Pacific northwest region. For vehicles with AER less than 20 miles, staff believes that there is a high likelihood that consumers may not utilize the zero-emission VMT potential. For example, it may be too much trouble for some consumers to "plug in" for very little zero-emission range. Consequently, they would not be eligible to receive zero-emission VMT allowance.

Some manufacturers are developing parallel hybrid electric vehicle designs that deliver improved fuel economy but do not have any significant all-electric range. Under this proposal, such vehicles would not qualify for a zero-emission VMT allowance because without wall re-charging capability that provides significant all-electric range, such vehicles would not exhibit the lowest emission characteristics. Consequently, such vehicles would not receive any zero-emission VMT allowance under this category, although they could receive some allowance under a provision explained later.

In addition, vehicles eligible to receive credit under this category that are equipped with software and/or other strategies allowing maximum realization of zero-emission VMT potential of the vehicle by promoting off-vehicle charging may qualify for an additional allowance of 0.1. The Executive Officer shall determine whether or not to approve the additional credit based on a number of factors including whether the strategy is tamper-proof, effective, or other similar factors.

Some vehicles have potential for zero-emissions for one regulated pollutant (e.g., NOx) while having low-levels of emissions of other regulated compounds (e.g., NMOG). One such vehicle could be an on-board methanol reformer fuel-cell vehicle. This vehicle has virtually no NOx emissions since the operational temperature of the reformer is typically lower than the temperature required for NOx formation. Consequently, in order to credit such vehicles for zero-emission capability of a specific pollutant, staff is proposing that this vehicle receive a zero-emission VMT factor of 0.5.

(ii) Allowance for vehicles that do not have any zero-emission VMT potential but are equipped with advanced ZEV componentry. Vehicles that do not have significant zero-emission VMT potential but are equipped with advanced batteries, an electric power-train, and/or other advanced ZEV technologies can qualify for a zero-emission VMT allowance of 0.1, subject to approval by the Executive Officer. This additional allowance is awarded in recognition of the vehicle's contribution to helping develop advanced batteries and powertrains that assist in commercializing ZEV technologies. One such vehicle would be the Toyota Prius, assuming it is designed to meet the SULEV standard. The Prius is equipped with a limited number of advanced nickel metal hydride (NiMH) batteries and an advanced electric drive-train.

(3) Low fuel-cycle emission allowance. Another characteristic that qualifies a vehicle to receive an additional ZEV allowance is the use of fuels with very low full fuel-cycle emissions to propel the vehicle. Under this proposal, a vehicle that uses fuel(s) with very low fuel-cycle emissions can receive a ZEV allowance up to a maximum of 0.2. The fuel-cycle emissions associated with a particular fuel are the total emissions associated with the production, marketing and distribution estimated as grams per unit of fuel. These emissions are then converted into grams/mile by applying the fuel-economy estimate of the vehicle. In order to receive this allowance, a manufacturer must demonstrate, using peer-reviewed studies or other relevant information, and subject to approval by the Executive Officer, that marginal NMOG emissions associated with the fuel used by the vehicle are lower than or equal to 0.010 grams per mile. It should be noted that for the purpose of awarding this allowance, fuel-cycle NOx emissions are not considered in the determination since marginal NOx emissions for virtually all fuels are uniformly very low. Fuel-cycle emissions must be calculated based on near-term production methods and infrastructure assumptions. At this time, it appears that only gaseous fuels could very likely qualify for this allowance. Some liquid fuels, for example methanol, may also qualify with vehicle efficiency improvements and with the use of zero-evaporative controls.

If more than one fuel is used to propel a vehicle, then this ZEV allowance is awarded based on the percent of total vehicle miles traveled using fuel(s) with low fuel-cycle emissions. To illustrate, assume a hybrid electric vehicle with significant all-electric range uses off-vehicle charging electrical energy to propel the vehicle for 30 percent of the total VMT and another fossil fuel (e.g. gasoline) for the remaining 70 percent of the total VMT. In this case, only the off-vehicle electrical energy use meets the low fuel-cycle emission requirement. Consequently, the ZEV allowance awarded to this vehicle would be 30 percent of 0.2, which is equal to 0.06.

(c) Summary of the partial ZEV allowance. The partial ZEV allowance awarded to a specific vehicle, then, is the sum of the allowances earned by the vehicle including the baseline, zero-emission VMT and low fuel-cycle emissions. The following summarizes the allowance proposal:

Table II-10
Partial ZEV Allowance Proposal

Characteristic	Pre-requisite or optional requirement?	ZEV allowance
Baseline allowance - Meets SULEV at 150K & 150K emission warranty	Pre-requisite for vehicles to receive any allowance	0.2
Zero-emission VMT allowance (1)(2)	Optional - qualifies vehicle for additional allowance	(0.6 x zero-emission VMT factor)
Low fuel-cycle emission allowance	Optional - qualifies vehicle for additional allowance	up to 0.2
Partial ZEV allowance		**Sum of the above**

(1) Additional allowance of 0.1 would be given to vehicles that employ strategies to maximize off-vehicle charging under the zero-emission VMT allowance category, subject to the condition that allowance in this category not exceed the maximum allowed value of 0.6.

(2) Vehicles that do not qualify for any zero-emission VMT factor can receive an additional ZEV allowance of 0.1 if those vehicles are equipped with advanced ZEV componentry such as advanced batteries, electric powertrain and other non-emission technologies.

(d) Limits on partial ZEVs towards meeting the ZEV requirements.

Applicable to large-volume manufacturers. Staff proposes to require that 40% of the ZEV requirement be met by true ZEVs and vehicles that receive a partial ZEV allowance of 1.0. This would serve to ensure sufficient production volumes of advanced battery electric vehicles, stored hydrogen fuel-cell vehicles or other non-emission vehicles that do not deteriorate. Maintaining this production requirement can help ensure continued technical development and pilot production process optimization and afford some economies of scale to help make these true zero-emitting vehicles affordable and more competitive in the 2005 to 2010 time frame.

Applicable to small and intermediate volume manufacturers. Small and intermediate volume manufacturers have indicated that it would be cost-prohibitive for them to individually produce very low volume advanced technology true ZEVs in the foreseeable future, given the relatively small number of vehicles that would be required to meet 40% of the ZEV requirement. Consequently, in order to address this concern, ARB proposes that small and intermediate volume manufacturers be allowed to satisfy the 10% ZEV requirement using only partial ZEV allowances, if they choose to do so.

(e) An additional incentive for ZEVs. In order to encourage manufacturers to produce zero-emission vehicles with relatively long driving range, which is one of the most important characteristics to consumers; staff is proposing to provide an additional incentive in the form of a ZEV multiplier. Only true ZEVs or vehicles that receive a partial ZEV allowance of 1.0 would be eligible to use these multiple credits. The following table details the number of ZEV credits as a function of range and model-year.

Table II-11
Multiple ZEV Credits

All-electric range, miles	MY 1999-2000	MY 2000 -2002	MY 2003-2005	MY 2006-2007
100-175	6-10	4-6	2-4	1-2

Note: Values for ranges in between 100 and 175 would be determined by linear interpolation between the values shown in the above schedule.

ZEVs that have a refueling time of less than 10 minutes (e.g. a stored hydrogen fuel cell vehicle) would be counted as having unlimited all-electric range and, consequently, would qualify to receive the maximum allowable ZEV credit for that model-year.

(f) This proposal allows the flexibility to use more than one qualifying technology to meet the ZEV requirements. Under this proposal, qualifying technologies receive an allowance ranging from 0.2 ZEV credit to multiple ZEV credits depending on their emission characteristics, use of advanced technologies to make vehicles that are more acceptable to consumers and other factors. Staff believes this proposal would provide manufacturers the flexibility to produce vehicles qualifying for ZEV credit that they envision would be most successful in the market-place and would best meet consumer expectations.

Overall, this proposal should allow considerable flexibility to manufacturers, incentivize new near-term zero-emission technologies, and maintain the true ZEV development efforts - eventually yielding more near zero emission reduction options than might otherwise be achieved. ARB staff encourages workshop participants to consider this proposal carefully, and to work with staff to constructively refine it in order to ensure fair and competitive treatment of all advanced technologies.

(g) Examples of the application of the proposal

Table II-12
Examples of Partial ZEV Allowance Calculation

Technology/Manufacturer	Baseline allowance	Zero-emission VMT allowance	Low fuel-cycle allowance	**Partial ZEV allowance** [3]
Gasoline SULEV	0.2	0.0	0	**0.2**
Hybrid gasoline SULEV with no AER, equipped with adv. batteries, electric powertrain	0.2	0.1	0	**0.3**
CNG SULEV	0.2	0.0	0.2	**0.4**
Gasoline Hybrid SULEV w/ 20-mile AER, off-veh. recharging	0.2	0.3	0.1	**0.6**

Technology/Manufacturer	Baseline allowance	Zero-emission VMT allowance	Low fuel-cycle allowance	**Partial ZEV allowance [3]**
On-board methanol reform. Fuel Cell (FC) vehicle	0.2	0.3[1]	0.2[2]	**0.7**
Hybrid SULEV with NIMH bat. (60 whr/kg) and 100-mile range.	0.2	0.6	0.2	**1.0**
On-board hydrogen FC vehicle w/ off-board partial oxidation reforming of hydrogen using fuel with low fuel-cycle emiss.	0.2	0.6	0.2	**1.0**

1) Assumes on-board methanol reformer produces virtually no NOx emissions
2) Assumes methanol has very low fuel-cycle emissions
3) Partial ZEV allowance= Baseline allowance + Zero-emission VMT allowance + Low fuel-cycle allowance

5. Proposed Amendments to Hybrid Electric Vehicle (HEV) Test Procedures.

(a) HEVs are complex, but require a relatively simple test procedure. As HEV technology progresses, it has become evident that adjustments need to be made to the HEV test procedures to accommodate emerging hybrid technologies. HEV technology combines a wide variety of energy storage devices (batteries, ultracapacitors and flywheels) with an equally diverse array of auxiliary power units (internal combustion engine, fuel cells, gas turbines or the sterling engine) and the operating strategy for managing vehicle operation can be very complex. However, the result is a vehicle that is capable of very low emissions and higher fuel economy than its conventional gasoline or diesel counterparts. Staff expects that HEVs will be one of the more promising technologies expected to meet the proposed SULEV emission standards.

A typical HEV combines a battery pack and an electric motor(s) with an auxiliary power unit (APU) to generate mechanical energy either to drive the wheels directly or to provide electricity for the battery pack and/or motor(s). There are two pathways for the energy to travel from the engine -- in series or parallel. In the case of a series HEV, the APU supplies electricity to the battery pack and/or to the electric motor(s) that in turn drives the wheels. The parallel HEV has two independent propulsion systems where the wheels are either driven by the APU mechanically or by the motor(s) when electricity is supplied by the battery pack. Although the series and parallel classifications provide a general description of HEV operation, this simplified view is not adequate to describe the more sophisticated HEV designs that direct APU energy to the wheels, battery pack, and motors in varying degrees.

While merging electric vehicle technology with conventional automobiles allows an HEV to operate as an electric vehicle at times and yet provide the driving range of a conventional vehicle, the added complexity makes it very difficult to develop a test procedure that adequately characterizes HEV operation. An HEV can shut off the APU during certain driving situations such as being stopped at a traffic signal in order to reduce emissions and conserve fuel and can even recover energy by regenerative braking, which uses the electric motors to convert the kinetic energy of the moving HEV back into electric energy that can be stored in a battery pack. HEVs can also be designed for all-electric operation by providing energy to the battery pack from an electric wall outlet. Most manufacturers, however, are not designing HEVs with significant all-electric range because of the added weight, complexity and cost of the battery pack. Indeed, a large battery pack is not necessary for HEVs and most tend to have smaller high power battery packs. Thus it is necessary to develop a test procedure that is flexible enough to accommodate all types of hybrid operating strategies but still ensures low emissions.

The task of evaluating and testing HEVs require test procedures to be comprehensive yet sufficiently flexible to address the wide variety of HEV technologies and specific enough to generate meaningful data. When developing the proposed HEV test procedures, staff wanted to ensure that the HEVs were tested using established conventional vehicle driving cycles while still ensuring that they operate within their design parameters during testing. Since this could add substantial testing burden, staff also endeavored to minimize test burden to the greatest extent possible without compromising data integrity.

By using standard test cycles for HEV testing, conventional vehicle emission standards would be applied for HEV certification. A fair assessment of HEV emission levels would require that HEVs not be forced to operate outside their design parameters. An example of an undesirable test condition would be to force the APU to operate during a driving situation when the APU would normally be shutoff. Further, the amount of testing that could be done on an HEV to test all possible modes of operation could become excessive. Therefore, staff focused on measuring emissions based on representative HEV operation over a given test cycle.

The staff proposal provides modifications to standard vehicle certification tests. Specifically, the Federal Test Procedure (FTP), the Highway Fuel Economy Test for measuring oxides of nitrogen emissions, and the Supplemental Federal Test Procedure (SFTP) are being modified to accommodate the diverse HEV operating strategies currently being developed by industry. Modifications to these certification tests involve establishing protocols for vehicle preconditioning and setting initial HEV battery state-of-charge for emission testing, and establishing criteria for determining valid emission tests.

While test procedures were being developed, three HEVs from Mitsubishi were available for evaluation. One of these HEVs was equipped with a gasoline fueled APU and lead-acid batteries while the other two were equipped with a compressed natural gas APU and lithium-ion batteries.

(b) Coordinating with the Society of Automotive Engineers (SAE) and U.S. EPA. Staff has been meeting regularly with the SAE for information sharing and technical input. The SAE hybrid testing procedure development committee consists of engineers from the auto industry and an environmental vehicle specialty company. This committee was formed several years ago to establish a standard HEV protocol known as Recommended Practice J1711 that measures both emissions and fuel economy. Other participants in this regular meeting include staff from the National Renewable Energy Laboratory who lend their expertise in conducting emission and fuel economy test modeling to evaluate test procedures. More recently staff from the U.S. EPA have joined in the discussions providing a perspective from the federal level. SAE has nearly completed J1711 and plans to send out a draft version of their procedures for review in August, 1998.

The proposed ARB procedures share some of the same requirements with J1711. For example, a type of HEV that is capable of operating without wall charging is classified as a charge sustaining HEV. As the classification implies, this HEV type sustains the battery pack charge indefinitely as long as the fuel supply for the APU is maintained. The J1711 and ARB common test protocol would require that the HEV battery pack end the emission test with as much energy as when the emission test began in order to be an acceptable test. The objective is to neither charge or deplete the battery by the end of the test. This is done to reflect the fact that in real world driving, the battery pack would be equally charged and discharged on average and result in no net change in battery pack energy level. Other common test practices exist between the two procedures.

Some of the differences between J1711 and the ARB procedures are primarily driven by the issue of fuel economy measurement. The ARB does not require fuel economy measurement for certification so that the ARB procedures focus on measuring emissions produced by the APU's highest emitting normal operating mode. On the other hand, J1711 includes fuel economy measurement as well as emission testing. To this end, J1711 requires that all driving modes available to an HEV operator be tested and the results equally weighted.

The ARB procedures as well as J1711 rely on accurately measuring battery state-of-charge (SOC) to determine valid emission testing. SOC, expressed in percent, represents the amount of electrical energy available relative to the total energy capacity of the battery. To determine battery SOC, battery voltage and current flow into and out of the battery must be measured as a function of time. The accuracy of determining SOC may be difficult since transient vehicle operation presents challenges in measuring the required electrical parameters. Although the ARB procedures rely on setting the initial SOC accurately for an emission test, staff believes that in the controlled environment of a test facility, this requirement is not difficult to achieve. Furthermore, once the initial SOC is set, the procedures would require that the net energy flow experienced by the battery be determined and not the actual SOC. For example, the test criterion for a valid charge-sustaining HEV test would require that the battery experience no net decrease in charge at the end of the test, as explained earlier.

Test-to-test repeatability may also prove to be difficult with HEVs. As more testing experience is acquired and if repeatability is indeed a challenge with HEVs, staff may alter the test procedures by requiring that an average of two or three tests be used. This does increase the testing time required for HEV certification but this may be the only solution to ensure that the emission data fairly represent the actual emission level of an HEV.

The U.S. EPA has recently begun investigating methods to test HEVs. Preliminary discussions indicate that the EPA is inclined to delay adopting HEV test procedures until more information is gained. The time frame that the EPA may promulgate HEV test procedures would be perhaps in the 2005 model year. Although the EPA may prefer to wait for more information before developing procedures, ARB adopted HEV procedures in 1993 and is now proposing to revise the procedures as new information has become available.

6. Proposed Amendments to Zero-Emission Vehicle Test Procedures. Staff is proposing some modifications to the certification and testing requirements for ZEVs primarily to incorporate suggestions to staff by industry regarding the test procedures. The proposed modifications include the adoption of a ULEV emission standard for the fuel fired heater when operating at ambient temperatures, the requirement to use a single roll electric dynamometer for more representative test results, specifications for a battery break-in period to ensure uniform testing and amendments to the driving schedules for the determination of all-electric range, and finally an ARB-generated requirement to submit battery DC energy data during charge and discharge events.

Amendments to the all-electric range test are aimed at facilitating electric vehicle (EV) testing. The changes being made would reduce test time while continuing to provide accurate results. Changes to the certification requirements for fuel-fired heaters would include a requirement that the heater meet ULEV emission levels at FTP test temperatures of 68°F to 86°F rather than meet SULEV emission levels tested at 40°F. Although the fuel-fired heater is not expected to operate above 40°F, manufacturers expressed concern that testing at this low level would be costly and time consuming. Since it is expected that the emission impact of the fuel fired heaters will be minimal due to operation limited to cold weather conditions when the potential for ozone formation is low, staff is proposing that the heater be tested at maximum output between 68°F and 86°F at a level not to exceed the ULEV standard, which should still be reasonably protective of air quality under heater operating conditions and would not require additional cold test facilities.

Manufacturers certifying EVs would be required to submit test data on vehicle performance and energy consumption that includes information on city and highway driving range, AC wallplug recharge energy use, and battery pack energy capacity measurements. Measurement of AC wallplug energy in AC kiloWatt-hours (AC kWhrs), combined with EV driving range test results, provides an AC energy-per-mile figure of AC Watthours per mile (AC Whr/mi). This information is important and is used by ARB to assess the air quality benefits of EVs based on powerplant emissions, as well as monitor technical progress in EV and battery development, and promote the use of efficient EV technologies.

Although current certification of EVs only requires manufacturers to submit AC wallplug energy use data during overnight charging, manufacturers are currently encouraged, but not required, to also submit DC battery output energy data during battery discharge (city/highway driving) and DC input energy data during overnight battery recharging. The new proposed certification requirements would include submittal of DC energy input and output at the EV battery pack. While AC energy can be directly used to determine ZEV emission levels, DC energy data would allow ARB to better understand and evaluate ZEV component performance and battery deterioration characteristics and the excess energy consumption that would result. Excessive battery, drivetrain or charger deterioration could result in significant AC energy usage that could lead to higher power plant emissions. Including the DC energy data in the certification application would provide a reliable, complete database each year that could be accessed when studying deterioration characteristics of in-use EVs years later. Because manufacturers are already providing this information for HEVs, staff does not believe requiring similar information for EV certification results in a significant hardship. Given the benefits that DC energy data offer to evaluating EVs in-use, it is important that ARB receive this information consistently each year.

7. Proposed Amendments to California Smog Index Label. Smog indices were adopted for light-duty vehicles in 1995 to provide consumers with an indication of the relative contribution of different new light-duty vehicles to smog formation based on exhaust and evaporative HC and NOx emissions from the vehicle. The smog index is calculated as follows:

$$\text{SMOG INDEX} = \frac{\text{exhaust NMOG (g/mi) + exhaust NOx (g/mi) + evaporative HC (g/mi)}\ \text{(new vehicle)}}{\text{exhaust NMOG (g/mi) + exhaust NOx (g/mi) + evaporative HC (g/mi)}\ \text{(baseline vehicle)}}$$

The current proposal updates smog index calculations based on new information that has become available and expands smog index calculations to incorporate changes to the Low-Emission Vehicle Regulations that are being proposed at this time for post-2003 model-year vehicles. Changes to smog index calculations are presented below.

(a) Modifications to the Smog Index for 2000-2003 Model Years. The following modifications are being proposed to the current Smog Indices.

Assign 2000 Model-Year Tier 1 Gasoline Passenger Cars a Smog Index Value of 1.00. When smog indices were originally developed, they were calculated based on the assumption that Tier 1 vehicles that certified to the 2.0 gram 1-hour diurnal plus hot soak evaporative emission standards would still be offered for sale when the smog index labeling requirements became effective. Beginning with the 1999 model-year, however, new vehicles will no longer be able to certify to the those evaporative emission standards. It is, therefore, more appropriate to recalculate smog indices recognizing that all new vehicles sold within the applicable time frame would meet more stringent new evaporative emission standards (2.0 gram 3-day diurnal plus hot soak hydrocarbon (HC) per test and 0.05 gram running loss HC/test). Hence, the proposed change would provide new vehicle purchasers a more accurate indication of how "clean" a new vehicle is relative to other new vehicles when the new smog indices become effective in 2000 and subsequent model-years.

Creation of a Single Set of Smog Indices for all Light-Duty Vehicles. As mentioned earlier, the current trend in light-duty vehicle purchasing is an increasing consumer preference for sport-utility vehicles and light pickups. An often overlooked consequence of this shift in vehicle selection is the air quality penalty associated with these heavier vehicles, which are currently subject to less stringent emission standards than passenger cars. It is unlikely there is much recognition by purchasers of new vehicles that the choice of these larger vehicles rather than conventional cars is detrimental to air quality. Therefore, until 2004, the ARB is proposing to adopt smog indices for all light-duty vehicles (and some medium-duty vehicles in 2004 and subsequent model-years) based on a single scale in which a Tier 1 gasoline passenger car is assigned a smog index of 1.00 (beginning with the 2004 model year, the ARB is proposing to adopt smog indices for all light-duty vehicles based on a single scale in which a TLEV gasoline passenger car is assigned a smog index of 1.00 - see subparagraph b. below).

Evaporative Emissions Estimate. Previous smog indices utilized in-use evaporative emissions of 0.14 g/mi. Based on EMFAC7G, the current estimate of g/mi evaporative HC emissions from passenger cars that certify to enhanced evaporative emission standards is 0.07 g/mi. Staff is proposing to update smog indices to reflect this new estimate.

Tier 1, Option 2 Diesels. Current smog index requirements do not specifically address vehicles certifying to the 100,000 mile (Tier 1, Option 2) diesel-specific standards of 0.31 g/mi NMHC, 4.2 g/mi CO, and 1.0 g/mi NOx. The current smog indices are based on Tier 1 gasoline vehicles certified to the old evaporative emission standards as a baseline. Thus the smog index for diesels certifying to Tier 1, Option 2 standards would be estimated using the allowable deterioration rate for those vehicles certifying to Option 1 standards. Estimated emission rates are indicated by an asterisk. While the hydrocarbon values are the same as for gasoline vehicles, NOx emission rates for diesels are clearly higher. This has been accounted for in the smog index.

Passenger Cars and Light-Duty Trucks 0-3750 lbs LVW

	NMHC		**NOx**	
	50k mi.	100k mi.	50k mi.	100k mi.
Option 1:	0.25 g/mi	0.31 g/mi	0.4 g/mi	0.6 g/mi
Option 2:	0.25 g/mi*	0.31 g/mi	0.67 g/mi*	1.0 g/mi

Light-Duty Trucks 3571-5750 lbs LVW

	NMHC		**NOx**	
	50k mi.	100k mi.	50k mi.	100k mi.
Option 1:	0.32 g/mi	0.40 g/mi	0.7 g/mi	0.97 g/mi
Option 2:	0.32 g/mi*	0.40 g/mi	1.08 g/mi*	1.5 g/mi

Fleet Average Smog Indices for Model Years 2000-2003. Staff is proposing the addition of fleet average smog indices that are intended to provide the consumer with an indication of the relative impact on ozone formation of a given vehicle relative to the "average" vehicle within the fleet. Calculation of fleet average smog indices requires an estimate of the percentage breakdown of passenger cars and trucks within California's fleet. California production numbers for the 1993 model year indicate that 79 percent of light-duty vehicles fall within the passenger car/T1 category and 21 percent fall within the T2 category. For the 2000-2003 model-years, the fleet average smog index calculations are based on these percentages. These fleet average smog indices were based on the suggested percentage implementation rates used to develop the fleet average NMOG requirements for LEVs.

(b) Smog Indices for 2004 and Subsequent Model Years. Staff based the 2004 and subsequent model year smog indices on the proposed LEV II standards, which include the following assumptions:

1. All light-duty trucks weighing 0-8500 lbs. GVW would be subject to the passenger car standards.

2. Beginning in 2004, vehicles would no longer be allowed to certify to Tier 1 standards. Therefore, a smog index of 1.00 would be assigned to a gasoline TLEV beginning with the 2004 model-year. Fleet average smog indices would be modified accordingly.

3. Proposed LEV and ULEV NOx emission standards for 2004 and subsequent model-year light- and medium-duty vehicles (0-8500 lbs. GVW) are 0.05 g/mi. The assumed phase-in of these standards is 25% in 2004, 50% in 2005, 75% in 2006 and 100% in 2007 and beyond.

4. Staff is proposing to establish a new category of emission standards for light-duty vehicles (0-8500 lbs. GVW) - super ultra-low-emission vehicles (SULEV). The NMOG and NOx emission standards for SULEVs that are being considered are 0.010 g/mi and 0.02 g/mi, respectively.

5. More stringent fleet average requirements are being proposed for 2004 and subsequent model-years that are based on the percentage implementation rates set forth in Tables II-7 and II-8, earlier.

6. Fleet average smog index calculations assume that the contribution of diesel vehicles certifying to Tier 1, Option 2 standards is negligible and all other vehicles certify to enhanced evaporative emission standards.

7. The Proposed Near-Zero and Zero Evaporative Emission standards would be phased in beginning in 2004, and finishing in 2006. The g/mi evaporative HC emissions

from vehicles certifying to the proposed “Near-Zero” and “Zero” evaporative emission standards have been calculated using a linear interpolation to the enhanced evaporative emission standards.

8. **Fleet Average Smog Indices for 2004 and Subsequent Model Years.** Calculation of fleet average smog indices for post-2003 model-years requires an estimate of the percentage breakdown of the passenger cars and trucks within California’s fleet. It is anticipated that the market for sport-utility vehicles and light pickups will increase to 50 percent of the new light-duty vehicle fleet over the next ten years. Consequently, the fleet average smog indices for the 2004-2010 model-years assume an even split between passenger cars and trucks 0-8500 lbs. GVW.

Based on these assumptions, staff is proposing adoption of the following smog indices and fleet average smog indices:

(b) 2000 through 2003 Model-Years:

The following smog indices shall apply to 2000 through 2003 model-year light-duty vehicles:

Table II-13
2000 - 2003 Smog Indices

	2.0g/ diurnal + hot soak test, 0.05 g/mi - running loss test, at 100,000 miles	**Evap. Exempt**	**Diesel Vehicle - Evap. Exempt**
LEV I			
Passenger Car/Light-Duty Truck 1 (0-3750 lbs. LVW)			
Tier 1	1.00	0.90	1.28
TLEV	0.83	0.73	n/a
LEV	0.48	0.38	n/a
ULEV	0.43	0.33	n/a
ZEV	n/a	0.00	n/a
Light Duty Truck 2 (3751-5750 lbs. LVW)			
Tier 1	1.51	1.42	1.94
TLEV	1.29	1.19	n/a
LEV	0.79	0.69	n/a
ULEV	0.72	0.63	n/a
ZEV	n/a	n/a	0.00

The following smog indices would apply to 2004 and subsequent model-year passenger cars and light-duty trucks 0-8500 lbs. GVW:

Table II-14
2004 and Subsequent Smog Indices

	Enhanced Evap. 2.0g/ diurnal + hot soak test, 0.05 g/mi - running loss test, at 100,000 miles	**PCs and LDTs 0.4 g/ diurnal + hot soak test, 0.01 g/mi - running loss test, at 150,000 miles**	**LDTs w/ fuel tank > 30 gallons 0.5 g/ diurnal + hot soak test, 0.01 g/mi - running loss test, at 150,000 miles**	**PCs and LDTs 0.2 g/ diurnal + hot soak test, 0.01 g/mi - running loss test, at 150,000 miles**	**Evap. Exempt**
LEV I					
Passenger Cars and Light-Duty Trucks (0-3750 lbs. LVW)					
TLEV	1.00	0.91	0.91	0.89	0.88
LEV	0.58	0.49	0.49	0.47	0.46
ULEV	0.52	0.43	0.43	0.42	0.40
ZEV	n/a	n/a	n/a	n/a	0.00
Light Duty Truck s (3751-5750 lbs. LVW)					
TLEV	1.56	1.47	1.47	1.46	1.44
LEV	0.96	0.86	0.87	0.85	0.84
ULEV	0.87	0.78	0.79	0.77	0.76
ZEV	n/a	n/a	n/a	n/a	0.00
LEV II					
Passenger Cars; Light Duty Truck s (0-3750 lbs. LVW); Light Duty Truck s (3751 lbs. LVW - 8500 lbs. GVWR)					
TLEV	1.00	0.91	0.91	0.89	0.88
LEV	0.33	0.23	0.24	0.22	0.21
ULEV	0.27	0.17	0.18	0.16	0.15
SULEV	0.17	0.07	0.08	0.06	0.05
ZEV	n/a	n/a	n/a	n/a	0.00

(d) Fleet Average Smog Indices

Model-Year 2000 Fleet Average Smog Index shall be 0.53
Model-Year 2001 Fleet Average Smog Index shall be 0.52
Model-Year 2002 Fleet Average Smog Index shall be 0.51
Model-Year 2003 Fleet Average Smog Index shall be 0.48

Model-Year 2004 Fleet Average Smog Index shall be 0.47
Model-Year 2005 Fleet Average Smog Index shall be 0.36
Model-Year 2006 Fleet Average Smog Index shall be 0.24
Model-Year 2007 Fleet Average Smog Index shall be 0.19
Model-Year 2008 Fleet Average Smog Index shall be 0.18
Model-Year 2009 Fleet Average Smog Index shall be 0.18
Model-Years 2010 and subsequent Fleet Average Smog Index shall be 0.17

C. TECHNOLOGICAL FEASIBILITY OF PROPOSED STANDARDS

Since adoption of the Low-Emission Vehicle regulations in 1990, emission control technologies have continued to evolve rapidly. In general, the emission control technologies on today's low-emission vehicles are less complex and involve less new hardware than the staff's initial projections in 1990. This is because both emission performance and durability of some familiar emission controls have significantly improved. In the early years of the LEV program implementation, virtually all low-emission vehicles were certified to the less stringent TLEV standard but as technologies improved and the fleet average decreased, the number of vehicles certified to the LEV and ULEV standards has increased accordingly.

In the 1998 model year, TLEVs comprise 43% of the new light-duty vehicles; LEVs make up 26% of new vehicles, and gasoline-powered ULEVs are now in the marketplace with the introduction of the ULEV Honda Accord. The number of LEVs and ULEVs will continue to increase in future model years as the fleet average decreases while TLEVs will commensurately decrease in numbers. In meeting the stringent LEV and ULEV standards, new vehicles have not generally required the use of new, sophisticated emission controls as some had predicted. Instead, refinements of Tier I technologies that have been utilized for years are being employed. Perhaps one exception to this trend is the Honda ULEV Accord. However, even with this vehicle, the use of more sophisticated technologies in certain areas (e.g., fuel control) allows Honda to reduce hardware and complexity in other areas (e.g., only one underfloor catalyst is used; no close-coupled catalyst is needed).

In December 1996, ARB staff provided its most recent update on the status of implementation of the LEV I program. At that public meeting, staff concluded that the technologies needed to comply with the current Low-Emission Vehicle program (with the most emphasis on meeting the more stringent ULEV emission category) were available and being utilized on many current vehicles. This conclusion was based on analyzing the emission controls on TLEVs and LEVs, and information available on ULEVs at that time. Since that last program update, staff's assessment has not changed significantly; in fact, the current technology projection for ULEVs is even simpler and less complex than the last update.

Many of the basic emission control approaches projected to be used on ULEVs have been utilized on new vehicles for several years to meet less stringent emission standards. The most significant improvements have been to traditional catalysts, which now warm up very rapidly and are substantially more durable than past technology, and to fuel control, which is much more precise and accurate than previous systems. In the following section, the technologies projected by ARB staff to be utilized on ULEV vehicles will be presented. This technology projection is based on the "matured" technology expected of 2003 model year ULEVs. Many of these technologies were described in the December 1996 status of implementation update and are presented here again for information purposes. A basic tenet of the original LEV program is that the vehicle technology and fuels must be linked to achieve the greatest emission reductions. This remains the case, as there is a growing body of evidence demonstrating that reducing sulfur content and modifying other parameters in both gasoline and diesel below current California levels would also significantly improve the emission performance of low-emission vehicles. Manufacturers believe that reducing fuel sulfur to near zero would be an important element for them to meet the proposed LEV II emission standards.

1. LEV I Emission Control Technology. While reducing emission levels of current vehicles is being achieved through various means, there are four basic aspects of current emission control systems that vehicle manufacturers have been improving to achieve low-emission levels. These are more precise fuel control, better fuel atomization and delivery, improved catalytic converter performance and reduced base engine-out emission levels. The emission control technologies being used for low-emission vehicles to comply with the LEV I program are listed in Table II-15. It is important to note that low-emission vehicles do not require the use of all of the technologies. The list just provides current low-emission technologies. The choices and combinations of low-emission technologies ultimately utilized by vehicle manufacturers are dependent on the engine-out emission levels of the vehicle, the effectiveness of the prior emission control system, and individual manufacturer preferences.

Table II-15

Low-Emission Vehicle Technologies	
Dual Oxygen Sensors	Engine Calibration Techniques
Universal Exhaust Gas Oxygen Sensors	Leak-Free Exhaust Systems
Individual Cylinder Air-Fuel Control	Increased Catalyst Loading
Adaptive Fuel Control Systems	Improved High-Temperature Washcoats
Electronic Throttle Control Systems	Electrically-Heated Catalysts
Reduced Combustion Chamber Crevice Volumes	Electric Air Injection
Sequential Multi-Point Fuel Injection	Full Electronic Exhaust Gas Recirculation
Air-Assisted Fuel Injectors	Hydrocarbon Adsorber Systems
Improved Induction Systems	Engine Designs to Reduce Oil Consumption
Close-Coupled Catalysts	Heat-Optimized Exhaust Pipes

(a) Technologies for Improving Fuel Control

Dual Oxygen Sensors. Maintaining the air-fuel ratio (A/F) at stoichiometric (where the amount of air is just sufficient to completely combust all of the fuel) is an important factor in achieving lowest engine emissions in three-way catalyst systems. In order for the emission control system to operate most efficiently, the A/F must remain within a very narrow range (less than 1% deviation) around stoichiometric. Modern vehicles have traditionally performed fuel control with a single oxygen sensor (O2S) feedback system. While this fuel control system is capable of maintaining the A/F with the required accuracy under steady-state operating conditions, the system accuracy is challenged under rapidly changing throttle conditions and is reduced as the sensor ages. Therefore, to improve fuel control and in-use emission performance at high mileage, most low-emission vehicles incorporate improved control algorithms combined with dual-oxygen sensors.

Since an O2S may not perform as accurately when it has aged, a second O2S placed downstream of one or more catalysts in the exhaust system can be used to monitor and adjust for deterioration of the front, primary sensor, thereby maintaining precise fuel control. Should the front O2S, which operates in a higher temperature environment, begin to exhibit slow response or drift in its calibration point, the secondary O2S is relied upon for modifying the fuel system controls to compensate for these aging effects. By placing the second sensor further downstream from the hot engine exhaust where it is also less susceptible to poisons, the rear sensor would not be likely to age significantly over the life of the vehicle. In this way, a dual O2S system maintains good fuel control -- and attendant low emissions -- as a vehicle ages. Because of their effectiveness, most light-duty vehicles now utilize dual oxygen sensors for fuel control. Manufacturers have also elected to use dual oxygen sensors on all new vehicles to accomplish the catalyst monitoring requirement of California’s On-Board Diagnostic II regulation.

Universal Exhaust Gas Oxygen Sensors (UEGOs). Vehicles that employ lean A/F control strategies (i.e., use less fuel than required to achieve a stoichiometric ratio) are utilizing one or more UEGOs for fuel control in lieu of conventional oxygen sensors. This is because conventional oxygen sensors cannot accurately measure A/Fs other than stoichiometric. Conventional oxygen sensors are "limit" switches in that they can only determine that the engine's A/F is higher or lower than stoichiometric; they do not have the capability of recognizing specific A/Fs. In contrast, UEGOs are capable of recognizing a wide-range of A/F since the voltage output of the UEGO is "linear" (i.e., each voltage value corresponds to a certain A/F). Therefore, maintaining a lean A/F is attainable with the use of UEGO sensors. Since operating lean of stoichiometric during cold-start situations can assist the heating of the catalysts, some low-emission vehicles incorporate these sensors. In addition to their capability of maintaining a tight lean A/F, some manufacturers claim UEGOs allow the fuel control system to maintain a tighter band around stoichiometric. In this way, UEGOs assist vehicles in achieving very precise control of the A/F. A small percentage of LEVs will rely on the use of UEGOs and it is projected that some ULEVs will as well.

Individual Cylinder A/F Control. In order to further improve fuel control, some ULEVs utilize software algorithms to perform individual cylinder fuel control. While dual O2S systems are capable of maintaining A/F ratios within a narrow range, some vehicle manufacturers believe that even more precise control is needed for ULEVs and a couple have already developed an individual cylinder control system. On most current vehicles, fuel control is modified whenever the O2S determines that the combined A/F of all cylinders in the engine or engine bank is "too far" from stoichiometric. The needed fuel modifications (i.e., inject more or less fuel) are then applied to all cylinders simultaneously. Although this fuel control method will maintain the "bulk" A/F for the entire engine or engine bank around stoichiometric, it would not be capable of correcting for individual cylinder A/F deviations that can result from differences in manufacturing tolerances, wear of injectors, or other factors. With individual cylinder fuel control, A/F variation among cylinders will be diminished, thereby further improving the effectiveness of the emission controls. By modeling the behavior of the exhaust gases in the exhaust manifold and using software algorithms to predict individual cylinder A/F, a feedback fuel control system for individual cylinders can be developed. Except for the replacement of the conventional front O2S with a UEGO sensor and a more powerful engine control computer, no additional hardware is needed in order to achieve individual cylinder fuel control. Software changes and the use of mathematical models of exhaust gas mixing behavior are required to perform this operation. UEGOs are currently being utilized by at least 2 vehicle manufacturers on 1998 model year vehicles.

Adaptive Fuel Control Systems. In order to maintain good driveability, responsive performance, and optimum emission control, fluctuations of the A/F must remain small under all driving conditions including transient operation. Virtually all current fuel systems incorporate an adaptive fuel control system that automatically adjusts the system for component wear, varying environmental conditions, varying fuel composition, etc., to more closely maintain proper fuel control under various operating conditions. For most fuel control systems today, this adaptation process affects only steady-state operating conditions (i.e., constant or slowly changing throttle conditions). However, most vehicles are now being introduced with adaptation during "transient" conditions (e.g., rapidly changing throttle, purging of the evaporative system).

Accurate fuel control during transient driving conditions has traditionally been difficult because of the inaccuracies in predicting the air and fuel flow under rapidly changing throttle conditions. Because of air and fuel dynamics (fuel evaporation in the intake manifold and air flow behavior) and the time delay between the air flow measurement and the injection of the calculated fuel mass, temporarily lean A/F ratios can occur during transient driving conditions that can cause engine hesitation, poor driveability and primarily an increase in NOx emissions. However, by utilizing fuel and air mass modeling, vehicles with adaptive transient fuel control are more capable of maintaining accurate, precise fuel control under all operating conditions. Virtually all LEVs and ULEVs will incorporate adaptive transient fuel control software.

Electronic Throttle Control ("Drive-By-Wire") Systems. As mentioned above, the time delay between the air mass measurement and the calculated fuel delivery presents one of the primary difficulties in maintaining accurate fuel control and good driveability during transient driving conditions. For vehicles that utilize a conventional mechanical throttle control, quick throttle openings can result in a lean A/F spike in the combustion chamber. Although air and fuel modeling algorithms can be developed to compensate for these time delay effects, some manufacturers are choosing to incorporate electronic throttle control to better synchronize the air and fuel flow to achieve proper fueling during transients (e.g., the driver moves the throttle, but the fuel delivery is momentarily delayed to match the inertial lag of the increased airflow). An increasing number of vehicles are expected to utilize this technology in the next few years.

(b) Technologies for Improving Fuel Atomization and Delivery

Sequential Multi-point Fuel Injection. Unlike conventional multi-point fuel injection systems that deliver fuel continuously or to paired injectors at the same time, sequential fuel injection can deliver fuel precisely when needed by each cylinder. With less than optimum fuel injection timing, fuel puddling and intake manifold wall wetting can occur, both of which hinder complete combustion. Use of sequential fuel injection systems help especially in reducing cold start emissions when fuel puddling and wall wetting are more likely to occur and emissions are highest. Because of the emission reductions and other performance benefits "timed" fuel injection offers, sequential fuel injection systems are now used on virtually all light-duty vehicles.

Air-Assisted Fuel Injectors. In addition to maintaining a stoichiometric A/F, it is important that a homogeneous air-fuel mixture is delivered at the proper time and that the mixture is finely atomized to provide the best combustion characteristics and lowest emissions. Poorly prepared air-fuel mixtures, especially after a cold-start and during the warm up phase of the engine, show significantly higher emissions of unburned hydrocarbons since combustion of the mixture is less complete. To further encourage a homogeneous mixture, air-assisted fuel injectors are being used. By providing better fuel atomization, more efficient combustion can be attained which should aid in improving fuel economy and reducing emissions. Since achieving good fuel atomization is difficult when the air flow into the engine is low, air-assisted fuel injection can be particularly beneficial in reducing emissions at low engine speeds. This technique improves idle smoothness, thereby permitting a lower engine idle speed and reduced fuel consumption. Further, industry studies have shown that the short burst of additional fuel needed for responsive, smooth transient maneuvers can be reduced significantly with air-assisted fuel injection due to a decrease in wall wetting in the intake manifold. Several manufacturers currently utilize these systems on some of their vehicles. ARB projects that about 50 percent of LEVs and ULEVs will eventually utilize air-assisted fuel injection.

Improved Induction Systems. Vehicle manufacturers are also incorporating improvements to the air induction system to enhance air-fuel mixing. Through the use of technologies such as variable intake systems and variable valve timing, the amount of swirl, turbulence, and velocity of the intake charge can be increased, especially during cold-start and low load operating conditions where sufficient swirl and turbulence tend to be lacking. By providing a strong swirl formation in the combustion chamber, the air-fuel mixture can mix sufficiently;

smooth, complete combustion can be achieved, thereby reducing emissions. All LEVS and ULEVs are projected to incorporate improved air induction systems.

(c) Technologies for Improving Catalyst Performance

Close-Coupled and Underfloor Catalysts. Three-way catalytic converters traditionally utilize rhodium and platinum as the catalytic material to control the emissions of all three major pollutants (hydrocarbons (HC), CO, NOx). Although this type of catalyst is very effective at converting exhaust pollutants, rhodium, which is primarily used to convert NOx, tends to thermally deteriorate at temperatures significantly lower than platinum. Recent advances in palladium and tri-metal (i.e., palladium-platinum-rhodium) catalyst technology, however, have improved both the light-off performance (light-off is defined as the catalyst bed temperature where pollutant conversion reaches 50% efficiency) and high temperature durability over previous catalysts. In addition, other refinements to catalyst technology such as higher cell density substrates and adding a second layer of catalyst washcoat to the substrate (dual-layered washcoats) have further improved catalyst performance from just a year ago.

Typical cell densities for conventional catalysts are 400 cells per square inch (cpsi). However, some vehicles available today use 600 cpsi catalyst substrates. If catalyst volume is maintained at the same level, using a 600 cpsi catalyst versus a 400 cpsi catalyst effectively increases the amount of surface area for reacting with pollutants. Catalyst manufacturers have been able to increase cell density without increasing thermal mass (and detrimentally affecting catalyst light-off) by utilizing thinner walls between each cell.

Double layer technologies allow optimization of each individual precious metal used in the washcoat. This technology can provide reduction of undesired metal-metal and/or metal-base oxide interactions while allowing desirable interactions. Industry studies have shown that durability and pollutant conversion efficiencies are enhanced with double layer washcoats. These recent improvements in catalysts are perhaps the most significant development that enable manufacturers to meet the LEV and ULEV standards at relatively low cost.

With the improvements in light-off capability, catalysts may not need to be placed as close to the engine as previously thought. However, if placement closer to the engine is still required for better emission performance, these improved catalysts would be more capable of surviving the higher temperature environment without deteriorating. Currently, many vehicles already utilize close-coupled catalysts. In the future, increasing numbers of vehicles are expected to utilize this technology as the emission standards become more stringent since close-coupling the catalysts to the engine can provide more heat, allowing them to become effective quickly.

Because of the improved performance of three-way catalysts, virtually all light-duty vehicles are expected to continue using this technology without the need for other aftertreatment devices such as electrically-heated catalysts (EHCs).

Heat-Optimized Exhaust Pipe. Improving insulation of the exhaust system is another method of furnishing heat to the catalyst. Similar to close-coupled catalysts, the principle behind insulating the exhaust system is to conserve the heat generated in the engine for aiding catalyst warm-up. Through the use of laminated thin-wall exhaust pipes, less heat will be lost in the exhaust system, enabling quicker catalyst light-off. As an added benefit, the use of insulated exhaust pipes will also reduce exhaust noise. Increasing numbers of manufacturers are expected to utilize air-gap exhaust manifolds (i.e., manifolds with metal inner and outer walls and an insulating layer of air sandwiched between them) for further heat conservation.

Engine Calibration Techniques. Besides the hardware modifications described above, low-emission vehicles also utilize engine calibration changes such as a brief period of substantial ignition retard, increased cold idling speed, and leaner air-fuel mixtures to quickly provide heat to a catalyst after cold-starts. Since only software modifications are required, engine calibration modifications provide manufacturers with an inexpensive method to quickly achieve light-off of catalytic converters. When combined with close-coupled catalysts and the other heat conservation techniques described above, engine calibration techniques can be quite effective at providing the required heat to the catalyst for achieving ULEV emission levels without auxiliary heating devices such as EHCs. Merely two years ago, the ARB projected that all ULEVs and some LEVs would require the use of EHCs to meet the requirements, but it now appears that nearly all vehicles will be able to achieve ULEV emission levels without requiring the assistance of an EHC. Heat producing engine calibrations such as described above are already in production and are projected to be incorporated on all low-emission vehicles.

Leak-Free Exhaust System. Improving exhaust systems to be leak-free also reduces emission levels. Air leaks in the exhaust system can cause an oxidation environment in the three-way catalyst at low speeds that would lead to an increase in NOx emissions. Also, should air leaks occur upstream or near the oxygen sensors, fuel control could be erratic and/or overly rich in response to the leaking unmetered air. This would not only affect driveability but also would increase emission levels. Because of their emission benefits, vehicle manufacturers will continue incorporating leak-free exhaust systems as the emission standards become more stringent.

The system typically consists of an improved exhaust manifold/exhaust pipe interface plus a corrosion-free flexible coupling inserted between the exhaust manifold flange and the catalyst to reduce stress and the tendency for leakage to occur at this joint. This system is already incorporated on many vehicles. Use of this type of system, assuming use of corrosion-free steel, can also reduce warranty costs due to customer complaints of noise from leaking joints. Further, improvement in the welding process for catalytic converter canning would assure less air leakage into the converter and provide reduced emissions. Virtually all low-emission vehicles will incorporate leak-free exhaust systems.

Electrically-Heated Catalysts. While the techniques described above will allow more heat to be provided quickly to the catalyst, some larger vehicles or those with tightly packaged engine compartments that require catalysts be placed underfloor may need additional help from auxiliary heating devices to achieve ULEV emission levels. Various strategies have been proposed to provide additional heat to the catalyst such as electrically-heated catalysts, exhaust gas burners, and energy storage devices. Of all these strategies, the electrically-heated catalyst has received the most attention since the technology has been shown to be feasible, cost-effective, and is ready to be introduced commercially.

In the early years of EHC development, there was concern that the electrical energy and power requirements needed to provide the heat energy necessary for ULEV emissions would require major upgrades to a vehicle's electrical system, including alternator upgrades, a separate dedicated battery to power the EHC and other electrical improvements. Recent advancements in EHC designs, however, have substantially reduced this concern. Most vehicles that utilize EHC systems will likely power the EHC directly from the alternator, or solely from the vehicle's battery, or from a combination of power from the vehicle battery and alternator.

Electric Air Injection. Although many ULEVs are expected to operate lean of stoichiometric or near stoichiometric after a cold-start, there will be some vehicle applications where this will not be possible because of driveability concerns. For these vehicles, a brief period of cold operation with a rich A/F mixture will be necessary. Although operating with a rich A/F mixture provides more stable combustion and better driveability when the engine is cold, it would also increase emissions of unburned HC and CO out of the engine. In order to control these emissions, vehicles that incorporate a rich cold-start fueling strategy are expected to include an electric air injection system to inject air upstream of the three-way catalyst so that a stoichiometric A/F ratio at the catalyst can be achieved for optimum emission performance. To further enhance quick catalyst light-off, ignition retard is being utilized with electric air injection to provide additional heat to the catalyst.

The use of air injection also appears likely on some EHC-equipped vehicles. With EHC systems, substantial reductions in HC and CO emissions can be achieved with air injection because the EHC can reach light-off temperature in about 3 seconds after starting the engine. Since NOx emissions are not a problem with a cold engine, the excess air that air injection provides should not significantly increase these emissions.

Unlike previous air injection systems that are powered by pumps driven by the engine, future air injection pumps will be electrically powered. Advantages of using electric air pumps include higher overall efficiencies, lower costs, increased reliability, and the ability to be turned off when not needed.

(d) Technologies to Reduce Engine-out Emission Levels

Reduced Crevice Volumes. Emission performance is also being improved by reducing crevice volumes in the combustion chamber. Unburned fuel can be trapped momentarily in crevice volumes before being subsequently released. Since trapped and re-released fuel can increase engine-out emissions, the elimination of crevice volumes would be beneficial to emission performance. To reduce crevice volumes, vehicle manufacturers are designing engines to include pistons with reduced top "land heights" (the distance between the top of the piston and the first ring). Although reducing the top land height could reduce the durability of the piston, improved design and materials allow moving the ring higher on the piston.

Reduced Oil Consumption. Lubrication oil which leaks into the combustion chamber also has a detrimental effect on emission performance since the heavier hydrocarbons in oil do not oxidize as readily as those in gasoline and some components in lubricating oil may tend to poison the catalyst and reduce its effectiveness. Also, oil in the combustion chamber may trap HC and later release them unburned. To reduce oil consumption, vehicle manufacturers are tightening the tolerances and improving the surface finish on cylinders and pistons, improving piston ring design and materials, and improving exhaust valve stem seals to prevent excessive leakage of lubricating oil into the combustion chamber. Virtually all low-emission vehicles with newly redesigned engines also incorporate features to reduce oil consumption.

Electronic Exhaust Gas Recirculation (EGR). One of the most effective emission controls for reducing NOx emissions is exhaust gas recirculation. By recirculating spent exhaust gases into the intake manifold to reenter the engine, peak combustion temperatures are lowered and NOx emissions are thus reduced.

Many EGR systems in today's vehicles utilize a control valve that requires vacuum from the intake manifold to regulate the EGR flow rate. Under part-throttle operation where EGR is needed, engine vacuum is sufficient to open the valve. However, during throttle applications near or at full-throttle, engine vacuum is too low to open the EGR valve. While EGR operation only during part-throttle driving conditions has been sufficient to control NOx emissions for most vehicles in the past, the more stringent NOx standards for LEVs and ULEVs and emphasis on controlling off-cycle emission levels may require more precise EGR control and additional EGR during heavy throttle operation to reduce NOx emissions. Vehicle manufacturers are increasingly using electronic EGR valve actuators in order to provide more precisely-controlled EGR rates for low emission levels. Therefore, use of these electronic systems allow engines to receive the optimal amount of EGR for all driving conditions.

Hydrocarbon Adsorber Systems. If the limiting factor for a vehicle to comply with the low-emission vehicle requirements is the control of HC, one possible solution could be HC adsorber systems. There have been several different types of HC adsorber systems proposed for use in motor vehicles over the past several years. Some of these systems are very complex with multiple valves, pipes, and heat exchangers while some are simpler in design and do not utilize any valves or other moving parts. Nonetheless, these systems all operate on the same principle. They are designed to trap the HC while the catalyst is cold and unable to convert the HC by utilizing an adsorbing material that holds onto the hydrocarbons. Once the catalyst is warmed up, the trapped HC are released from the absorption material and directed to the fully functioning downstream three-way catalyst. While this principle sounds simple, the technical solution is not uncomplicated, because the adsorption and desorption of the HC need to be timed correctly to prevent premature release of the unburned HC (i.e., the HC must be released only after the catalyst has warmed-up). Staff has been informed by some manufacturers that HC adsorbers may be used on some LEVs and ULEVs that have severe underhood space constraints. One HC adsorber system has recently received tentative approval for incorporation of an adequate monitoring strategy for meeting On-Board Diagnostics II requirements.

2. Projected LEV II Technologies (PCs and Trucks ≤ 8500 lbs.)

As described earlier, the proposal for LEV II would require significant NOx reductions not only for vehicles in the current light-duty vehicle category but also would include trucks and SUVs up to 8500 lbs. GVW. In addition, although NMOG and CO emission standards would remain at the same LEV I levels for current light-duty vehicles, the under 8500 lbs. GVW trucks and SUVs would require more significant reductions of these emissions to comply with the proposed LEV II requirements. To meet these new requirements, staff believes that additional refinements to mature LEV I technology will allow the majority of cars and trucks to comply with LEV II standards. In the following section, LEV II technologies that would be incremental to the LEV I technologies described earlier will be discussed in more detail. Similar to the step needed to improve Tier I vehicles to LEV I levels, the primary means for additional reductions will rely on improvements to aftertreatment, fuel control and delivery, and engine-out emissions.

(a) Increased Catalyst Volume and Substrate Cell Density. As mentioned in the previous section, increasing catalyst volume and substrate cell density can significantly improve catalyst performance. Typical LEV I (LEV and ULEV) passenger cars currently have catalyst volume/engine displacement ratios of about 0.7 to over 1.0 while many trucks have ratios of 0.6 or less. In order to comply with the new combined LEV II standards, most vehicles will likely need catalyst volumes greater than the displacement of their engines. During the 2003-2004 timeframe it is projected that all cars and trucks subject to the LEV II requirements will typically utilize 600 cpsi catalyst substrates for good pollutant conversion efficiencies especially in close-coupled locations. Since these higher cell density substrates effectively provide more surface area for pollutant conversion, catalyst volumes may not need to be increased as much as with conventional substrates to achieve LEV II levels. Industry papers also indicate that work on substrates with cell densities as high as 900 cpsi is now being conducted with promising results. On vehicles with large underfloor catalysts, however, industry technical papers have indicated that the effectiveness of high cell density substrates are not as significant. This behavior may be due to the high pressure drop across the catalyst.

(b) Increased Catalyst Loading and Improved Washcoats. In addition to increasing catalyst volume and cell density, staff projects that increased catalyst loading and improved catalyst washcoats will also be needed to achieve LEV II emission levels. In general, increased noble metal loading (up to a certain point) will reduce exhaust emissions because it increases the opportunities for pollutants to be converted to harmless constituents. Typical catalyst loading on current LEVs and ULEVs range from less than 50 g/ft^3 to as high as 300 g/ft^3.

To achieve LEV II levels, staff believes that catalysts will be loaded to the 100 - 300 g/ft^3 range. Precious metal loading will be dependent upon the precious metals used and other catalyst design parameters (e.g., warm-up catalysts tend to have higher loadings than underfloor catalysts in multi-catalyst systems). A recent development that staff believes is very promising are palladium/rhodium catalysts. Since rhodium is very efficient at converting NOx, catalyst suppliers have been investigating increasing the amount of rhodium in catalysts for improved NOx conversion.

Palladium/rhodium catalysts have been installed on some ARB test vehicles and are being evaluated now. Initial ARB 50,000 mile aging performance results on these vehicles have been promising. While at least one vehicle manufacturer has stated that palladium/rhodium catalysts are thermally more sensitive than other catalyst technologies (i.e., palladium-only) and would deteriorate more noticeably with mileage, staff believes that based on discussions with some suppliers and our own test results, improved washcoat designs (e.g., double-layer washcoats) will reduce thermal deterioration on these catalysts.

Thus, washcoat design will be very important for achieving and maintaining LEV II emission levels. New washcoat formulations are now thermally stable up to 1050 ^{o}C. This is a significant improvement from conventional washcoats, which are stable only up to about 900 ^{o}C. This improved resistance to high temperature degradation should allow close-coupled catalysts to maintain their emission performance even under severe driving conditions. Continued work on improving catalyst performance will likely result in even better thermal durability and emission performance in the near future.

(c) Improved Catalyst Light-off with Secondary Air Injection (SAI) and Retarded Spark Timing. It is well established that a warmed-up catalyst is very effective at converting exhaust pollutants. Recent tests on advanced catalyst systems have shown that over 90% of emissions during the Federal Test Procedure (FTP) are now emitted during the first two minutes of testing after engine start up. Although improvements in catalyst technology have helped reduce catalyst light-off times, additional help may be needed to achieve LEV II emission levels. There are several methods to provide additional heat to the catalyst many of which have already been described in the previous section such as EHCs, and ignition retard with or without electric air injection. It is projected that all LEV II vehicles will utilize ignition retard and that many also include electric air injection.

(d) 1998 Light-Duty Vehicle Technology Estimates for LEV II Program. The following tables summarize the ARB's 1998 estimates of the technologies being used in the LEV I program and likely to be utilized in LEV II to meet the LEV and ULEV standards.

Table II-16 4-Cylinder Vehicles

LEV standard			ULEV standard		
Technology	LEV I	LEV II	Technology	LEV I	LEV II
Sequential fuel injection	X	X	Sequential fuel injection	X	X
Improved fuel preparation			Improved fuel preparation	50%	50%
Precise fuel-air control	X	X	Precise fuel-air control	X	X
UEGO (front-only)			UEGO (front-only)	X	X
Full electronic EGR	X	X	Full electronic EGR	X	X
Retarded spark-timing at start-up		X	Retarded spark-timing at start-up		X
Leak-free exhaust	X	X	Leak-free exhaust	X	X
Close-coupled catalyst	X	larger	Close-coupled catalyst	X	X
Underfloor catalyst			Underfloor catalyst	X	X
Improved double-layer washcoat +600 cpi cell density	X	X	Improved double-layer washcoat +600 cpi cell density	X	X
Increased catalyst loading			Increased catalyst loading		X

Table II-17 6-Cylinder Vehicles

LEV standard			ULEV standard		
Technology	LEV I	LEV II	Technology	LEV I	LEV II
Sequential fuel injection	X	X	Sequential fuel injection	X	X
Improved fuel preparation			Improved fuel preparation	50%	50%
Precise fuel-air control	X	X	Precise fuel-air control	X	X
UEGO (front-only)			UEGO (front-only)	50%	50%
Full electronic EGR	X	X	Full electronic EGR	X	X
Retarded spark-timing at start-up		X	Retarded spark-timing at start-up		X
Leak-free exhaust	X	X	Leak-free exhaust	X	X
Close-coupled catalyst	X	X	Close-coupled catalyst	X	X
Underfloor catalyst		X	Underfloor catalyst	X	X
Improved double-layer washcoat +600 cpi cell density	X	X	Improved double-layer washcoat +600 cpi cell density	X	X

LEV standard			ULEV standard		
Increased catalyst loading		X	Increased catalyst loading		X
Air-injection			Air-injection		50%

Table II-18 8-Cylinder Vehicles (passenger cars, trucks & sport-utility vehicles)

LEV standard			ULEV standard		
Technology	LEV I	LEV II	Technology	LEV I	LEV II
Sequential fuel injection	X	X	Sequential fuel injection	X	X
Improved fuel preparation		50%	Improved fuel preparation	50%	50%
Precise fuel-air control	X	X	Precise fuel-air control	X	X
UEGO (front-only)		50%	UEGO (front-only)	50%	50%
Full electronic EGR	X	X	Full electronic EGR	X	X
Retarded spark-timing at start-up	X	X	Retarded spark-timing at start-up	X	X
Leak-free exhaust	X	X	Leak-free exhaust	X	X
Dual close-coupled cat.	X	X	Dual close-coupled cat.	X	X
Dual secondary catalyst	X	X	Dual secondary catalyst	X	X
Improved double-layer washcoat +600 cpi cell density	X	X	Improved double-layer washcoat +600 cpi cell density	X	X
Increased catalyst loading		X	Increased catalyst loading		X
Air-injection			Air-injection	50%	X

3. Medium-Duty Vehicles (8,500 - 14,000 lbs. GVW). Under the proposed LEV II exhaust emission standards, auto manufacturers are also required to substantially reduce emissions from medium-duty-vehicles (MDVs). Of the two categories remaining in this class of vehicles using the new classification, vehicles with 8,501 - 10,000 lbs. GVW are the focus in this technical assessment for MDVs. Currently there are no MDVs in the 10,001 - 14,000 lbs. GVW category that are chassis certified, and few are expected in the future. However, any such vehicles would likely employ much of the technology of the 8,5001 - 10,000 lbs. GVW category. Currently, to meet the existing emission standards for this category of vehicles, manufacturers are essentially using many of the same emission control technologies they are employing on their LDVs. These technologies include dual heated oxygen sensors, sequential multi-point fuel injection, exhaust gas recirculation, three way-catalysts, and in some cases secondary air injection as shown in the following table. However, a more extensive use of available technologies would likely be needed to comply with the proposed LEV II requirements. A brief description of the staff's projection of the technologies for MDVs is described below.

(a) Catalyst system changes. In order to achieve the emission reductions called for in LEV II, manufacturers would likely rely on improvements in existing emission control technologies and placement of the catalysts closer to the engine. Vehicles in this class utilize V-8 engines with dual exhaust banks. In some vehicles, the two banks are joined with a "Y" pipe and only a single underfloor catalytic converter is used. On vehicles with dual exhaust systems, one underfloor catalytic converter is used for each bank. Furthermore, some vehicles also employ warm-up catalysts. To meet the LEV II requirements, manufacturers would likely still utilize underfloor catalytic converters, however, the location of the converter would likely be moved closer to the engine to reduce light-off time (for some vehicles, space constraints near the engine may preclude manufacturers from using this strategy without making modifications to the underfloor/engine compartment layout). In addition, dual warm-up catalysts using ceramic or metallic substrates may be added to further improve emission performance. Although, metallic substrates are usually more expensive than ceramic substrates, some believe they may require less precious metal loading than ceramic substrates due to the reduced light-off times they provide. In addition, manufacturers are expected to use advanced catalyst formulations with improved washcoat technologies and higher precious metal loadings. These advanced catalysts would utilize washcoats in which separate layers are applied on the substrate for each precious metal. This type of layered design provides an opportunity to tailor the washcoats for optimum performance of each precious metal. This double layer technology also improves the aging stability of the converters, especially in the case of palladium-rhodium catalysts.

(b) Other emission control system improvements. Further reductions in exhaust emissions can be achieved by lowering engine out emissions and utilizing improved fuel preparation and delivery. Currently, only a small percentage of vehicles use secondary air injection. This technology may be used in a larger number of vehicles to lower HC emissions during cold start and to lower NOx through more rapid heating of the catalyst to achieve earlier NOx conversion capability. Most EGR systems used in current MDVs are already electronically controlled. Since reduction of NOx emissions is the primary target under the LEV II requirements, further refinements of the EGR control algorithms may be needed. Staff anticipates that electronic EGR will be utilized on all vehicles in this category. Manufacturers may also adopt changes in engine calibrations that provide ignition timing retard and higher idle speeds during cold start in order to supply more heat to the catalyst for quicker light-off times to further reduce HC and NOx emissions.

The following table summarizes staff's estimate of the technology strategies that are being used in the LEV I program and would be used for meeting the LEV II medium-duty emission standards.

Table II-19
Medium-Duty LEV II Technologies

LEV standard	ULEV standard

Technology	LEV I	LEV II	Technology	LEV I	LEV II
Sequential fuel injection	X	X	Sequential fuel injection	X	X
Improved fuel preparation		X	Improved fuel preparation	50%	50%
Precise fuel-air control	X	X	Precise fuel-air control	X	X
UEGO (front-only)		50%	UEGO (front-only)	50%	50%
Full electronic EGR	66%	X	Full electronic EGR	X	X
Retarded spark-timing at start-up		X	Retarded spark-timing at start-up		X
Leak-free exhaust	X	X	Leak-free exhaust	X	X
Dual close-coupled cat.	33%	33%	Dual close-coupled cat.	33%	33%
Dual small thermal close-coupled cat.*			Dual small thermal close-coupled cat.*	66%	66%
Dual underfloor catalyst	66%	66%	Dual underfloor catalyst	100%	100%
Single underfloor catalyst	33%	33%	Single underfloor catalyst		
Improved double-layer washcoat +400 cpi cell density		X	Improved double-layer washcoat +400 cpi cell density		X
Increased catalyst loading		X	Increased catalyst loading		X
Air-injection	33%	X	Air-injection	50%	X

* Limited space constraints in some applications may preclude the use of traditional close-coupled catalysts.

4. LEV II Technological Evaluation Program ARB is conducting two test programs to help evaluate the feasibility of lower NOx standards for these vehicles - one for trucks and the other for passenger cars. Both test programs are relying primarily on installing advanced catalyst systems on test vehicles to achieve lower emission levels (the original catalysts are being replaced with advanced catalysts). However, some alterations to calibrations of EGR, ignition timing, secondary air injection, and fuel control may be attempted where applicable. Although the staff will attempt to gain an estimate of the emission reduction capability and durability of advanced catalysts through this effort, our limited access to modifying fuel and spark timing strategies or to alter other engine systems restricts our ability to achieve what expert automotive engineers can achieve given their comparatively enormous resources and experience plus another 5 to 7 years of development time. Staff also expects catalysts to continue to improve as well beyond today's impressive performance. All of these factors, plus consideration of vehicle and emission measurement variability and other issues will be further considered before staff proposes the final emission standards. Each of the test programs is discussed in more detail below.

(a) Passenger Car Test Program. A total of six recent model-year gasoline-powered vehicles are being evaluated for LEV II emission capability. Each of the 6 test vehicles was tested for baseline emissions at approximately 4000 miles before any modifications to the vehicle's emission controls were made. The average emissions from these FTP tests are listed in Table II-20. After these baseline FTP results were complete, new advanced catalysts were installed on each test vehicle. In general, the advanced catalysts were placed in the same position as the OEM catalysts. There are only 2 vehicles that have catalysts added to the OEM configuration and these catalysts are small pipe converters. FTP tests were then conducted on the cars. If the emission results were not below the proposed LEV II standards with a reasonable cushion, engine calibration modifications such as ignition retard at engine start, O2 sensor biasing, and air injection modifications were applied on the affected vehicles to reduce tailpipe emission levels. Approximately 4000 miles have been or will be accumulated on the "green" catalysts before FTP tests are conducted again. The emission test results for the modified and unmodified advanced catalyst vehicles are listed in Table II-21.

On some cars, bench aging of the catalyst systems to 50,000 miles may be performed. This will be dependent on the availability of bench aging time and resources.

Table II-20
Average FTP emissions of OEM test vehicle at approximately 4000 miles.

Test Vehicle	NMHC (g/mi)	CO (g/mi)	NOx (g/mi)
1997 Mercury Sable	0.035	0.9	0.072
1998 Mercury Grand Marquis	0.048	0.6	0.014
1998 Buick Park Avenue	0.039	0.6	0.189
1998 Nissan Altima	0.031	0.7	0.040
1998 Toyota Avalon	0.044	0.4	0.111
1998 Honda Accord EX	0.025	0.3	0.066

Table II-21
Average FTP emissions of test vehicle with modifications and advanced catalysts.

Test Vehicle	Approx. Mileage on Adv. Catalyst	NMHC (g/mi)	CO (g/mi)	NOx (g/mi)	Modifications
1997 Mercury Sable	0	0.029	1.0	0.036	Air Injection Time
1998 Mercury Grand Marquis	4000	0.033	0.5	0.004	None
1998 Buick Park Avenue	2500	0.037	0.8	0.028	Ignition Retard
1998 Nissan Altima	0	0.028	0.7	0.033	Fuel Biasing
1998 Toyota Avalon	N/A	N/A	N/A	N/A	N/A
1998 Honda Accord EX	0	0.026	0.4	0.035	Ignition Retard

(b) TRUCK/SUV Technical Feasibility Testing. In order to evaluate the capability of achieving LEV II ULEV levels on trucks and SUVs, ARB procured two commercially available, identically equipped 1998 Ford Expeditions. The Expedition was chosen for this demonstration since it represents the upper tier of the vehicle weight category and exhibits very capable emission performance relative to other vehicles in this category. The technical specifications of the two vehicles, identified hereafter as Vehicle #2 and Vehicle #3, are listed in the following table.

Table II-22
Technical Specifications for 1998 Ford Expedition (Vehicles #2, #3)

Class	MDV3
Engine	5.4 Liter V-8 Triton Engine
Transmission	4 speed automatic
Tires	P255/70R16
Body style	Sport Utility
Drive Type	RWD, 4 X 4
Engine Family	WFMXA05.4JGC
Test Weight	6000 lb
Aftertreatment	Dual three-way catalysts X 2 Dual heated oxygen sensors X 2 Exhaust gas recirculation Sequential multi-port fuel injection
Calibration	8-46U

Vehicle #2 was emission tested over the FTP cycle in the baseline OEM configuration. The results are presented below:

Table II-23 Vehicle #2 Testing
Expedition (Vehicle #2) Baseline FTP Emissions OEM Configuration

Catalyst Config	Odometer Miles	NMHC g/mi	CO g/mi	NOx g/mi	CO_2 g/mi	Fuel Econ mi/gal
OEM	1432	.084	1.486	.025	655.92	13.03
OEM	1451	.080	1.501	.023	658.86	12.97
OEM	1471	.085	1.913	.044	666.83	12.81
OEM	1490	.090	1.986	.024	655.45	13.03
OEM	1509	.089	1.878	.036	657.21	12.99
OEM	1528	.090	1.476	.022	669.34	12.80
OEM	1547	.098	1.994	.028	669.28	12.76
OEM	1559	.098	1.788	.035	664.41	12.86
	Average	.089	1.753	.030	662.16	12.91

Vehicle #2 was modified to provide air injection to the exhaust manifold so that lower NMHC and CO emissions could be achieved at cold start. Various air flow rates and on and off strategies were tested. Modest reductions in NMHC and CO emissions could be attained as shown in the table below:

Table II-24 Expedition (Vehicle #2)
Baseline FTP Emissions with Air Injection*

Catalyst Config	Odometer Miles	NMHC g/mi	CO g/mi	NOx g/mi	CO_2 g/mi	Fuel Econ mi/gal
OEM	1835	.053	1.266	.040	660.29	12.98
OEM	1858	.057	1.522	.033	640.07	13.38
OEM	2431	.054	.752	.049	667.91	12.85

*The results shown represent tests utilizing air injection ending within 30 seconds after start-up.

ARB obtained a non-aged advanced Pd/Rh advanced catalyst system for Vehicle #2. The catalyst system and the oxygen sensors from Vehicle #2 were bench-aged at the Southwest Research Institute Laboratory, in San Antonio, Texas. Bench-aging was performed to simulate 50,000 in-use miles using a representative cycle specified by Ford Motor Company for this vehicle. The fuel used to bench-age the catalyst was a 30 ppm Phase 2 reformulated California fuel. After bench-aging, the catalyst system and oxygen sensors were shipped back to ARB, installed on Vehicle #2, and tested for emissions. Due to limited time, the combination of advanced catalyst and air injection was not tested.

Table II-25
Expedition (Vehicle #2) FTP Emissions
After Advanced Catalyst & O_2 Sensors Bench-Aged to 50,000 miles
Using 30 ppm Sulfur Phase II CA Fuel

Catalyst Config	Odometer Miles	NMHC g/mi	CO g/mi	NOx g/mi	CO_2 g/mi	Fuel Econ mi/gal
Advanced	2466	.115	3.684	.042	662.35	12.86
Advanced	2486	.107	3.048	.062	661.00	12.91
Advanced	2497	.105	3.276	.046	663.03	12.86
	Average	.109	3.336	.050	662.13	12.88

Vehicle #3 Testing

Vehicle #3 was also emission tested over the FTP cycle in the baseline OEM configuration and emission results similar to that of Vehicle #2 were obtained:

Table II-26
Expedition (Vehicle #3) Baseline FTP Emissions OEM Configuration

Catalyst Config	Odometer Miles	NMHC g/mi	CO g/mi	NOx g/mi	CO_2 g/mi	Fuel Econ mi/gal
OEM	2322	.069	1.752	.026	665.32	12.84
OEM	2398	.076	1.784	.022	655.39	13.03
OEM	2421	.070	1.486	.021	654.61	13.06
OEM	2436	.073	1.586	.042	666.66	12.82
OEM	2455	.084	1.678	.036	664.73	12.85
OEM	2474	.083	1.528	.041	658.06	12.90
	Average	.076	1.636	.031	660.80	12.92

ARB obtained a second identical non-aged advanced catalyst system (as used in Vehicle #2) and installed it in the non-aged condition on Vehicle #3. Four thousand on-road miles were driven on the vehicle/catalyst system and emission tests were performed.

Table II-27

Expedition (Vehicle #3) FTP Emissions with 4,000 mile Advanced Catalyst

Catalyst Config	Odometer Miles	NMHC g/mi	CO g/mi	NOx g/mi	CO_2 g/mi	Fuel Econ mi/gal
Advanced	6554	.117	2.450	.020	660.83	12.93
Advanced	6565	.084	1.671	.024	660.38	12.97
Advanced	6577	.077	1.429	.016	656.88	13.04
Advanced	6596	.086	1.661	.019	661.34	12.95
Advanced	6607	.085	1.573	.022	652.09	13.13
Advanced	6626	.092	1.857	.022	654.69	13.07
	Average	.090	1.774	.021	657.70	13.02

The catalyst system and the original oxygen sensors were removed from Vehicle #3 and shipped to the Southwest Research Institute Laboratory for bench-aging. Bench-aging was identical to that performed on the Vehicle #2 catalyst system and oxygen sensors, except a 300 ppm sulfur fuel was used as called for in the standard Ford aging procedure. The bench-aged catalyst system and oxygen sensors were shipped back to ARB, installed on Vehicle #3, and tested for emissions over the FTP cycle. Despite the high sulfur content of the fuel used in bench-aging, emission results were similar to those of Vehicle #2, which used a low sulfur fuel meeting Phase 2 reformulated California certification fuel specifications. It should be noted that all FTP emission tests on the Expeditions were conducted using Phase 2 reformulated California Certification fuel containing 30 ppm sulfur.

Table II-28
Expedition (Vehicle #3) FTP Emissions After Advanced Catalyst and O_2 Sensors Bench-Aged to 50,000 miles Using 300 ppm Sulfur Fuel

Catalyst Config	Odometer Miles	NMHC g/mi	CO g/mi	NOx g/mi	CO_2 g/mi	Fuel Econ mi/gal
Advanced	6783	.106	2.567	.043	649.93	13.14
Advanced	6810	.115	2.953	.065	650.18	13.12
Advanced	6821	.095	2.641	.028	651.45	13.11
Advanced	6832	.108	2.796	.039	651.78	13.10
Advanced	6844	.110	2.489	.051	656.62	13.01
Advanced	6863	.128	3.650	.077	643.09	13.24
Advanced	6874	.121	3.272	.064	644.09	13.24
	Average	.112	2.910	.052	649.59	13.14

To counter the effects of bench-aging the catalyst system with high sulfur fuel, a sulfur removal cycle, as specified by the Coordinating Research Council (CRC), was performed on Vehicle #3. This cycle is a high speed, wide-open-throttle test driven on the dynamometer that subjects the catalyst to high inlet temperatures and rich air/fuel conditions. Emission tests performed after the sulfur removal cycle tended to show a shift in NMHC, CO and NOx emissions. However, despite the high catalyst inlet temperatures, NOx emissions remained about the same. The trend of these tests, however, shows a gradual increase in emissions, which is currently being investigated.

Table II-29
Expedition (Vehicle #3) After CRC Sulfur Removal Cycle
(Advanced Catalyst & O_2 Sensors Bench-Aged to 50,000 miles Using 300 ppm Sulfur Fuel)

Catalyst Config	Odometer Miles	NMHC g/mi	CO g/mi	NOx g/mi	CO_2 g/mi	Fuel Econ mi/gal
Advanced	6920	.144	3.942	.049	644.21	13.21
Advanced	6946	.128	4.102	.044	646.30	13.17
Advanced	6965	.138	4.351	.071	658.48	12.92
Advanced	6976	.139	4.003	.061	651.63	13.06
Advanced	6987	.156	4.218	.091	655.75	12.97
Advanced	7025	.150	4.386	.042	660.25	12.89
Advanced	7044	.183	4.995	.103	661.07	12.84
	Average	.148	4.285	.066	653.96	13.01

5. Low-Emission Measurement. Accurate measurement of vehicle emissions is needed to provide manufacturers with the assurance that they have achieved the targeted emission levels for their vehicles. Furthermore, uncertainties in emission measurements could result in differences in vehicle emission measurements between the manufacturers' and regulatory agencies' test facilities. This could prove problematic in determining whether the manufacturers are in compliance with the standards. The test procedures and sampling techniques used currently were designed for measuring emissions from vehicles emitting on the order of 0.1 g/mi hydrocarbons and oxides of nitrogen. At the low levels being proposed, manufacturers are concerned that emission measurements may not be reliable enough to accurately measure vehicle emissions.

In response to the low emission standards adopted by the ARB in 1990, the American Industry/Government Emissions Research Consortium (AIGER) was formed. The members of AIGER are; ARB, General Motors, Ford, Chrysler, and the U.S. EPA. The purpose of the AIGER consortium is to explore the development of new instrumentation and sampling techniques for low-emission vehicles. Several AIGER projects have shown promise in providing more accurate measurement at low levels and are expected to mature in the near future. Furthermore, the manufacturers of emission measurement instrumentation have been working to improve the measurement capability of their current equipment. These improved instruments have generally been incorporated into the manufacturers' and regulatory agencies' test facilities. ARB has made several incremental improvements to its test facility to enhance emission measurement at low levels. These improvements consist of: installation of a single roll electric dynamometer for more consistent vehicle loading from test to test, installation of a variable volume sampling system and a remote mixing tee with heated dilution air to reduce condensation of the exhaust sample, and lower instrument ranges. In the near future, ARB is planning to heat the dilute exhaust ducting to the bag sample orifice and replace all teflon tubing with stainless steel to reduce the occurrence of sample hang up interfering with instrument performance.

ARB has been testing vehicles emitting at ULEV emission levels since 1990, and has not encountered significant problems with measuring at these low levels or experienced unusual test-to-test variability. In 1994, ARB tested a ULEV prototype Honda Accord equipped with an advanced emission control system. The vehicle was also tested at Honda's facility in Los Angeles with very good agreement between the two facilities. Recently, ARB performed confirmatory emission testing of the Honda natural gas Civic with certification emission levels one tenth of the current ULEV standard and again achieved good agreement with Honda's test facility in Japan. Staff recognizes, however, that further improvements in emissions measurement capability are needed and will continue to work with industry and the USEPA to improve emission test equipment and methods.

D. REGULATORY ALTERNATIVES

Staff considered the following regulatory alternatives to the proposed LEV II exhaust amendments.

1. Do not amend current California LEV Program. Measure M2 of the California SIP calls for additional ROG plus NOx emission reductions from light-duty vehicles using advanced emission control technology. In order to accomplish these goals, the current LEV emission standards need to be amended to incorporate more stringent emission standards that could be achieved using advanced control technology. The targeted emission reductions in Measure M2 would not be achieved unless lower standards were proposed.

2. Adopt Federal Tier 2 Standards. Federal language requires U.S. EPA to adopt, under certain conditions, more stringent light-duty vehicle emission standards, known as Tier 2 standards. These standards are similar to the current California LEV standards, although U.S. EPA may choose to adopt more stringent standards if needed. The U.S. EPA is currently investigating the feasibility of adopting lower light-duty vehicle emission standards that could be commensurate with the proposed LEV II standards. These standards are anticipated to be promulgated some time in the next few years with an anticipated 2004, 2005 or 2006 model year implementation date. However, because California's air pollution problems are unique and more severe than in other parts of the country, staff determined that in order to achieve the emission reduction goals of SIP Measure M2, it would be necessary to implement standards that were specific to California and would achieve the necessary emission reductions beginning with the 2004 model year.

3. Adopt Less Stringent LEV II Standards. Staff believes that the proposed LEV II standards are technologically feasible and cost-effective. Any consideration of less stringent standards could potentially put the state at the risk of not achieving the emission reduction goals of SIP Measure M2. In order to provide more flexibility to manufacturers when phasing in the LEV II standards, staff is proposing a very flexible phase in schedule that allows manufacturers to implement the new standards based on their production schedules.

E. ENVIRONMENTAL IMPACT AND COST-EFFECTIVENESS ANALYSIS

1. Environmental Impact. California's plan for achieving the federal ambient ozone standard is contained in the California State Implementation Plan (SIP) that was approved by the Board in 1994. The SIP calls for emission reductions of 25 tons per day (tpd) of ROG plus NOx by 2010 from light-duty vehicles (Mobile Source Measure M2) and additional emission reductions in the South Coast Air Basin of approximately 75 tpd ROG plus NOx (the inventory of these emissions is referred to as the "Black Box"). While the SIP is designed to obtain benefits statewide, the targeted level of control is based on the emission reductions needed for the South Coast Air Basin (SoCAB) because it is the only nonattainment area in the United States designated as extreme and extra controls will be needed to bring this area into attainment. Although the emission reduction strategies identified in this report target the SoCAB, the remainder of the state would also benefit from the strategies identified for this basin.

Based on an analysis of the emission inventory, it is anticipated that the proposed LEV II modifications will achieve the 25 tpd ROG + NOx emission reductions required by Measure M2 as well as providing approximately 35 tpd ROG + NOx reductions needed to reduce the emissions attributable to the Black Box by 2010. The following describes staff's inventory model, the corresponding assumptions made concerning the light- and medium-duty vehicle fleet and the anticipated emission reductions attributable to the proposed LEV II emission standards and restructuring of the light-duty truck category.

In determining the anticipated emission reductions, staff relied on the current emission inventory model, MVEI7G adjusted to account for the projected growth rates for trucks and SUVs, with concomitant changes to the vehicle mix from passenger cars to light-duty trucks. The vehicle mix used in this analysis, 51% for passenger cars, 33% for light-duty trucks, and 16% for medium-duty vehicles less than 8,500 lbs. GVW, was based on recent quality audit data that suggests an increase in the number of trucks and a decrease in the number of passenger cars from the current model levels of 60% for passenger cars, 28% for light-duty trucks and 12% for medium-duty vehicles under 8500 lbs. GVW. The total population of these vehicles, the number of vehicle miles traveled per vehicle and the number of starts per vehicle were held constant. In addition, staff assumed that all passenger cars, light-duty trucks and medium-duty vehicles less than 8,500 lbs. GVW would meet the same emission standards (see Table II-4 which contains the proposed LEV II emission standards) and used the “possible percentage implementation rates” contained in Table II-7 and II-8 with a 25%/50%75%/100% implementation rate assumed for NOx implementation beginning in the 2004 model year. It should also be noted that the baseline includes the reductions attributable to the Supplemental Federal Test Procedure standards.

The total reductions from the LEV II proposal for passenger cars, light-duty trucks and medium-duty vehicles less than 8,500 lbs. GVW for 2010 are as follows:

Table II-30
LEV II EMISSION REDUCTIONS IN 2010 (SoCAB)

2010	PCs	LDTs <6000 lbs. GVW	MDVs 6000 - 8500 lbs. GVW	Total TPD Reduction
ROG	1.24	1.11	1.67	4.02
CO	50.16	52.91	41.88	144.95
NOx	15.84	21.79	17.63	55.26

Staff anticipates additional emission reductions attributable to the proposed lower standards for medium-duty vehicles over 8500 lbs. GVW. However, this information was unavailable at the date of release of this preliminary staff report. Additional emission reductions beyond 2010 will be realized as the fleet fully turns over to LEV II vehicles.

(b) **Cost-Effectiveness of LEV II Exhaust Proposal.** Staff is currently in the process of determining the cost of meeting the proposed LEV II standards and should have the information available at the workshop.

III. SUMMARY OF EVAPORATIVE AND REFUELING EMISSION PROPOSAL

A. BACKGROUND

1. Evaporative Emissions. Evaporative hydrocarbon (HC) emissions are classified into three types: running loss, hot soak, and diurnal emissions. Running loss emissions occur when the vehicle is driven and can originate from numerous sources within the fuel system and from fuel vapor overflow of the on-board carbon canister. Hot soak emissions occur immediately after a fully-warmed up vehicle is stationary with the engine turned off and are due to high underhood temperatures. Diurnal emissions occur when a vehicle is parked and are caused by daily ambient temperature changes. Most of these emissions result during increasing ambient temperatures which cause an expansion of the vapor in the fuel tank.

The main evaporative emission control device is the on-board carbon canister. Excess fuel vapors in the fuel tank are routed to the carbon canister for storage rather than release into the atmosphere. The carbon canister is regenerated during vehicle operation when the HC vapors stored in the canister are purged into the engine's intake system and subsequently burned in engine combustion. Evaporative emissions from the canister occur when the generated fuel vapors going to the canister are greater than its storage capacity, and thus, breakthrough of the canister occurs. Another main source of evaporative emissions is through permeation of hoses, joints, and plastic fuel tanks. Elastic hoses, made of rubber, plastic, and other materials, are used in areas of the fuel system where flexibility is needed. Other sources are engine breathing losses, fuel cap leakage, and leaks in the fuel system.

Beginning in the 1995 model year, the "enhanced" evaporative standards and test procedures were implemented, requiring effective control of each of the three types of evaporative emissions. Despite notable evaporative emission reductions with the enhanced evaporative regulation, approximately half of the HC motor vehicle emission inventory projected for 2010 statewide continues to be evaporative emissions. Thus, due to its significant contribution to the HC emission inventory, a reduction in evaporative emissions beyond that achieved by the enhanced regulation would improve air quality in California.

2. Refueling Emissions. During a refueling event for a motor vehicle, fuel tank vapors are volumetrically displaced by the incoming liquid fuel. The Stage 2 Vapor Recovery Regulation requires that these fuel tank vapors be routed to the underground storage tank of the gasoline dispensing facility rather than be released into the environment. Starting with the 1998 model year, the On-Board Refueling Vapor Recovery (ORVR) Regulation took effect, requiring that the fuel tank refueling vapors instead be routed and stored on-board the vehicle. On ORVR-equipped vehicles, the vehicle evaporative emission control canister may also be used for capturing the refueling vapors. Vapor losses during a refueling event are known as refueling HC emissions. The sources of these emissions include displaced vapor from the vehicle fuel tank, vapor loss from the fuel, and fuel spitback. The ORVR regulation requires at least 95 percent efficiency in capturing refueling vapors, and this is achieved with a few hardware modifications to the vehicle's fuel and evaporative control system.

B. PROPOSED AMENDMENTS TO CALIFORNIA'S ENHANCED EVAPORATIVE AND REFUELING EMISSION REGULATIONS ("ZERO-EVAP")

The staff recommends that the Board adopt new evaporative emission and refueling standards by amending sections 1976 and 1978, Title 13, California Code of Regulations (CCR), and to incorporate the new documents, "California Evaporative Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles" and "California Refueling Emission Standards and Test Procedures for 2001 and Subsequent Model Motor Vehicles." The proposed evaporative emission and refueling standards are separate requirements that a manufacturer must design its vehicles to comply with and would require more effective control of the three types of evaporative emissions and of refueling emissions. Under consideration are also minor modifications to the evaporative test procedure for the measurement of low level evaporative emissions, to allow abbreviated test procedures for "zero" evaporative vehicles, and for testing of vehicles under conditions more representative of a California summer day. These modifications are still under development and are not included in this draft staff report; staff will continue to work with motor vehicle manufacturers to develop these additional provisions.

1. Proposed Evaporative/Refueling Emission Standards.

(a) **Evaporative Emission Standards.** The staff proposes two new classes of evaporative emission standards: "near-zero" and "zero." Tables III-1 and III-2 show the proposed "near-zero" evaporative emission standards and the proposed "zero" evaporative emission standards, respectively, for the running loss test, the three-day diurnal-plus-hot-soak test, and the two-day diurnal-plus-hot-soak test. The proposed standards are expressed in total vehicle HC evaporative emissions. As in the case of the current standards, they are applicable to gasoline-fueled, liquefied-petroleum-gas-fueled, and alcohol-fueled passenger cars, light-duty trucks, medium-duty vehicles, and heavy-duty vehicles. For flexible-fuel vehicles, dual-fuel vehicles, hybrid-electric vehicles, and zero-emission vehicles with fuel fired heaters, the standards apply for operation on the applicable fuel. Note the proposed LEV II vehicle categories for light-duty trucks and medium-duty vehicles are reflected in the tables. As discussed in Part II, the upper weight limit of the light-duty truck category would be increased from 6,000 lbs. GVW to 8,500 lbs. GVW. Consequently, it would eliminate the previous medium-duty vehicle category in that range. The medium-duty category over 8,500 lbs. GVW would remain unchanged.

The proposed "near-zero" standards are an 80 percent reduction from the current evaporative standards, except for the proposed two-day diurnal-plus-hot-soak standards for incomplete medium-duty vehicles and heavy-duty vehicles. For these vehicles, the percent reduction is almost 90 percent. The current three-day diurnal-plus-hot-soak emission standards applicable to incomplete vehicle certification of medium-duty and heavy-duty vehicles are lower than those applicable to complete large vehicle certification, because the incomplete vehicle demonstration of evaporative emissions and deterioration is based only on an engineering evaluation rather than actual testing of the system. Thus, staff is proposing similarly lower standards for incomplete medium-duty and heavy-duty vehicle certification than those for complete large vehicle certification. In addition, the current two-day diurnal-plus-hot-soak standards for incomplete vehicles are not consistent with the three-day diurnal-plus-hot-soak standards in that they are numerically higher than those for complete vehicle certification. For consistency with the three-day diurnal-plus-hot-soak standards, staff proposes lower incomplete vehicle two-day diurnal-plus-hot-soak standards. Note that the proposed three-day diurnal-plus-hot-soak standards are slightly lower than the proposed two-day diurnal-plus-hot-soak standards to reflect that the three-day diurnal-plus-hot-soak standards are technology forcing. The main function of the two-day diurnal-plus-hot-soak standards will be to ensure adequate purging of the carbon canister during vehicle operation. Compliance with the proposed "near-zero" standards would require improvements to conventional evaporative/fuel systems, as discussed in Section III.C.

The proposed "zero" evaporative standards are shown in Table III-2. The proposed standards essentially require negligible fuel evaporative HC emissions, with an allowance for non-fuel vehicle HC emissions. These emissions originate from off-gassing of the vehicle upholstery, carpet, paint, tires, and other sources that are believed to decrease exponentially over time to a nominal value. The proposed "zero" running loss standards are equivalent to the proposed "near-zero" running loss standards at 0.01 grams per mile, because repeatability and accuracy of emission measurements at much lower levels become more difficult. Compliance with the "zero" evaporative standards would require substantial improvements to conventional evaporative/fuel systems and may required more advanced evaporative/fuel systems. The technological feasibility of the "zero" evaporative standards is discussed in Section III.C. As noted above, staff is currently developing a proposal to allow abbreviated testing for the certification of the "zero" evaporative vehicle.

Table III-1. Proposed "Near-Zero" Evaporative Emission Standards

Class of Vehicle	Hydrocarbon Standards		
	Running Loss (grams per mile)	Three-Day Diurnal + Hot Soak (grams per test)	Two-Day Diurnal + Hot Soak (grams per test)
Passenger Cars	0.01	0.4	0.5
Light-Duty Trucks			
with fuel tanks < 30 gallons	0.01	0.4	0.5
with fuel tanks ≥ 30 gallons	0.01	0.5	0.6

Class of Vehicle	Hydrocarbon Standards		
	Running Loss (grams per mile)	Three-Day Diurnal + Hot Soak (grams per test)	Two-Day Diurnal + Hot Soak (grams per test)
Medium-Duty Vehicles (8,501 - 14,000 lbs. GVWR)	0.01	0.6 [(1)]	0.7
	0.01	0.4 [(2)]	0.5
Heavy-Duty Vehicles (over 14,000 lbs. GVWR)	0.01	0.4	0.5
Hybrid Electric PCs, LDTs and MDVs	0.01	0.4	0.5

(1) The standards in this row apply to medium-duty vehicles certified according to the exhaust standards in Title 13, CCR, Section 1961.

(2) The standards in this row apply to incomplete medium-duty vehicles certifying to the exhaust standards in Title 13, CCR, Section 1956.8.

Table III-2. Proposed "Zero" Evaporative Emission Standards

Class of Vehicle	Hydrocarbon Standards		
	Running Loss (grams per mile)	Three-Day Diurnal + Hot Soak (grams per test)	Two-Day Diurnal + Hot Soak (grams per test)
Passenger Cars	0.01	0.2	0.2
Light-Duty Trucks	0.01	0.2	0.2
Medium-Duty Vehicles (8,501 - 14,000 lbs. GVW)	0.01	0.3 [(1)]	0.3
	0.01	0.2 [(2)]	0.2
Heavy-Duty Vehicles (over 14,000 lbs. GVW)	0.01	0.2	0.2
Hybrid Electric PCs and LDTs	0.01	0.2	0.2

(1) The standards in this row apply to medium-duty vehicles certified according to the exhaust standards in Title 13, CCR, Section 1961.

(2) The standards in this row apply to incomplete medium-duty vehicles certifying to the exhaust standards in Title 13, CCR, Section 1956.8.

(b) **Refueling Emission Standard.** The proposed refueling emission standard is 0.04 grams per gallon applicable to gasoline-fueled, diesel-fueled, and alcohol-fueled passenger cars and light-duty trucks under 8,500 lbs. GVW and to the applicable fuel operation for flexible-fuel vehicles, dual-fuel vehicles, hybrid-electric vehicles, and zero-emission vehicles with fuel-fired heaters. The proposed standard represents an increase of vapor capture efficiency from the current 95 percent to 99 percent and is an 80 percent reduction from the current standards. An exemption from testing is allowed for vehicles on diesel fuel operation if a manufacturer attests that due to the inherent characteristics of the fuel and vehicle fuel tank temperatures, the vehicle can meet the proposed standards without a control system. The applicability of the proposed refueling standard and exemption for vehicles on diesel fuel operation are unchanged from the current refueling regulation.

2. Proposed Useful-Life Requirement. The current useful-life requirement in which the vehicle must comply with the applicable evaporative and refueling emission standards is 10 years/100,000 miles for passenger cars and light-duty trucks, 11 years/120,000 miles for medium-duty vehicles, and 8 years/110,000 miles for heavy-duty vehicles. The staff is proposing to extend the current useful-life requirements of the proposed evaporative and refueling emission standards to 15 years/150,000 miles for all vehicles. This proposed evaporative/refueling useful-life requirement is longer than the proposed exhaust emission durability of 10 years/120,000 miles. Staff believes that evaporative/refueling emission deterioration is significantly lower than that of exhaust emissions, primarily because the evaporative/refueling emission control components are subjected to substantially less stress, such as the high temperatures of combustion gases, and thus are much less likely to deteriorate significantly over its lifetime. Certification data have shown that despite rigorous aging of the evaporative/refueling components for the duration of current useful-life requirements, very little, if any, emission deterioration is observed. By extending the useful-life requirement to 15 years/150,000 miles, additional protection of evaporative/refueling emissions is ensured throughout the in-use life of the vehicle.

3. Proposed Phase-in Schedule. The staff proposes the phase-in schedule in Table III-3 for the implementation of the proposed evaporative and refueling standards. Since the proposed evaporative and refueling standards are separate requirements, the proposed phase-in percentages are independent of each other and may be met with different vehicle mix/evaporative families. As shown, the proposed implementation schedule is 40 percent in the 2004 model year, 80 percent in the 2005 model year, and 100 percent in the 2006 and subsequent model years. The proposed evaporative standards have two phase-in schedules, one for the "near-zero" evaporative standards and the other for the "zero" evaporative standards. Full implementation of the proposed evaporative standards would occur in the 2006 model year, with 20 percent of the vehicles certified to the "zero" evaporative standards and 80 percent certified to the "near-zero" evaporative standards. The 20 percent "zero" evaporative requirement would promote the development of substantially improved conventional evaporative/fuel systems with the use of improved materials and a completely sealed system, and the development of advanced evaporative/fuel systems. This modest phase-in percentage would allow the introduction of vehicles with improved evaporative/fuel systems that have essential zero fuel evaporative emissions. Staff is also considering an optional phase-in schedule to allow early implementation of the "near-zero" and "zero" evaporative standards before the 2004 model year.

Table III-3. Proposed Phase-in Implementation Schedule for the Evaporative and Refueling Standards

	2004 MY	2005 MY	2006 and subsequent MY
Total Evaporative Standards	40	80	100
"Near-Zero" Evap Standards	35	70	80
"Zero" Evap Standards	5	10	20
Refueling Standards	40	80	100

C. TECHNOLOGICAL FEASIBILITY AND COST ANALYSIS OF EVAPORATIVE EMISSION PROPOSAL

1. Proposed Evaporative Emission Standards. Two sets of analyses for the proposed evaporative standards are presented below. The first analysis performed is for the proposed "near-zero" evaporative emission standard of 0.40 grams per test diurnal-plus-hot-soak, with a running loss standard of 0.01 grams per mile. Staff believes these standards can be met with relatively simple improvements to current evaporative/fuel systems. The second analysis performed is for the "zero" evaporative emission standard of 0.20 grams per test, with the running loss standard again at 0.01 grams per mile. Staff believes that these standards can be met with more robust systems such as pressurized systems or completely sealed fuel and evaporative systems.

(a) "Near-Zero" Evaporative Standards. Technological feasibility for the proposed "near-zero" evaporative standards has been studied in two phases: modifying and testing of vehicles meeting the proposed emission standard levels, and an assessment of the hardware changes manufacturers will need to make on vehicles to comply with proposed emission standards.

Vehicle Testing. In the first phase, ARB staff will test six 1998 model-year vehicles; the expected completion date for the test program is July 1998. The test vehicles have already been procured: five of these vehicles are selected based on low certification evaporative emission values, and the sixth (the Malibu) is procured as a vehicle with average certification emission values. Vehicle descriptions are given in Table III-4 below. These vehicles are tested initially in the as-received condition, and are tested thereafter in a modified configuration until the lowest evaporative emission levels are reached. Testing is conducted using Phase II certification fuel on the ARB's three-day diurnal-plus-hot-soak evaporative procedure and a shortened version of this procedure. For both tests, diurnal test temperatures from 65°F to 105°F are used, with hot soak testing performed at 105°F. Running loss testing was not conducted. Detailed description of the testing methodology is given in the Zero-Evaporative Emission Test Plan, contained in Appendix H.

Table III-4. Test Program Vehicles

Vehicle	Engine Displacement
Toyota Corolla	1.8 L
Toyota Camry	2.2 L
Toyota Avalon	3.0 L
Hyundai Accent	1.5 L
Honda Civic	1.6 L
Chevrolet Malibu	3.1 L

In general, the same modification procedure was applied to each vehicle although not every modification was performed on every vehicle. The first modification was the use of an additional canister to catch any vapors that would ordinarily be emitted from the vehicle canister. The use of an additional canister was not envisioned as an actual design scenario for manufacturers to use; it was intended to represent the use of a segmented or chambered canister which would yield virtually zero (~0.01 g) daily emissions when tested under these conditions. The next modification then made was the addition of a carbon intake air filter adjacent to the clean side of the normal air filter. This additional filter served to greatly reduce the hydrocarbon vapors that are gradually emitted to the environment from the engine during diurnal episodes and hot soaks.

Following these modifications, fuel system connections were sealed, using a combination of Tedlar (a non-permeable plastic) and shrink tape. In this case, the shrink tape served to hold the sealing material in place tightly against the fuel system connection. Rubber/plastic fuel lines are also wrapped with a combination of two different plastic films. Both films are generally believed to be impermeable to fuel hydrocarbons which would normally permeate through rubber/plastic fuel lines.

The last series of modifications that ARB staff performed are the sealing of the fuel filler-neck (a corrugated elastic tube connecting the fuel tank to the vehicle fill-pipe, where gasoline is introduced during a refueling event), and the sealing of the fuel pump assembly exterior. The fuel pump is mounted inside the fuel tank and sends gasoline to the engine. Although the assembly is sealed from the interior and exterior, significant vapor leaks occur at this seal in current vehicles. The ARB staff sealed the fuel filler neck using the same Tedlar-shrink tape method as previously described for the fuel system connections. In addition, the filler neck itself was sealed using the same type of plastic films utilized for the fuel system hoses. In order to seal the fuel pump assembly, Tedlar was used to re-seal the original seal, using an automotive gasket sealant. Finally, an improved, stiffer gas cap without a relief valve was used that showed fewer evaporative emissions than the standard OEM gas cap.

To date, three vehicles have been modified and evaporative emission tested. The previous series of modifications yielded significant emission reductions for each vehicle, as shown in Table III-5 below:

Table III-5. Test Data from the Evaporative Test Program

Vehicle	Baseline - Diurnal + Hot Soak Results (g/test)	Final Result - Diurnal + Hot Soak Results (g/test)	Reduction (g/test)
Toyota Corolla	0.278	0.220	0.058
Toyota Camry	0.525	0.337*	0.188
Toyota Avalon	0.544	0.307	0.237
Average	0.449	0.288	0.161

* Only tested in final configuration using “shortened” test; final results using the three-day diurnal-plus-hot-soak test will be conducted and are expected to be similar.

The final diurnal-plus-hot-soak average result of 0.288 grams per test is well below the proposed standard of 0.40 grams per test, and allows for compliance margin for issues such as production tolerances and test cell-to-test cell variability. It should be noted that a manufacturer may choose to use non or low HC emitting vehicle materials, such as interior trim and body paint, to help comply with the proposed standard.

No running loss tests or two-day diurnal-plus-hot-soak tests were performed. However, it appears likely that the running loss standards and two-day diurnal-plus-hot-soak standards can be reduced proportionately to the three-day diurnal-plus-hot soak standards since they have the same emission sources. The proposed 80 percent reduction in the three-day diurnal-plus-hot-soak emission standard then yields the proposed running loss standard of 0.01 grams per mile and the two-day diurnal-plus-hot-soak standard of 0.5 grams per test when this percentage reduction is applied.

Cost Analysis. The preliminary cost analysis, per vehicle, is calculated as follows. The materials used in the ARB’s testing have been shown effective in reducing evaporative emissions below the proposed standards. However, manufacturers will need to use more robust materials in some areas of the vehicle to ensure that the vehicle maintains low emission levels over the proposed 15-year/150,000 mile in-use compliance requirement. Below are the materials the ARB staff expects manufacturers to use for compliance with the “near-zero” standards:

-Chambered construction carbon canister
-Additional carbon air intake filter
-Improved low-permeation materials for fuel hoses
-Improved low-permeation material for fuel filler-neck
-Lower permeation plastic fuel tanks
-Improved connections for fuel lines such as “banjo” fittings

-Improved joint connections for fill-pipe, filler-neck, and fuel tank assembly
-Improved seal for fuel pump assembly
-More robust gas cap

Staff expects the above hardware changes to cost approximately $15-$40 per vehicle, with the main uncertainty being the cost of the improved connections, sealing of the fuel pump assembly and plastic fuel tanks. Staff will continue to develop the cost analysis by obtaining information from motor vehicle and parts manufacturers to refine this preliminary analysis.

For the chambered construction canister, staff expects manufacturers to modify existing canister designs (which often contain some form of chambered construction) to be even lower-emitting. This would be accomplished through the use of more chambers, which serve to minimize vapor migration towards the exit vent of the canister. In addition, the intake air carbon filter can be included as a supplement to the main air filter, or built into this filter itself.

For the fuel hoses, filler neck, and plastic gas tank, lower-permeation materials may be required. One such material currently available is the Viton class of fluoroelastomer from DuPont Dow Elastomers. This material can be used for elastic applications such as hoses and filler-necks. It reduces permeation by approximately 90 percent when compared with materials such as nylon-12, a material in common use today. Staff also believes plastic fuel tanks permeation can be reduced with improved barrier layer technology.

As indicated above, staff expects that improved metal-to-metal fittings, such as “banjo” fittings, will be used in the areas where connection or joint losses are a problem, such as fuel system connections. Banjo-fittings are a pressure-tight metal-to-metal fitting commonly used in applications where internal vacuum, or no-leakage conditions are necessary. These fittings are already in use today in fuel hose-fuel rail connection on some vehicles, where the high fuel system pressure requires a tight seal for fuel containment. Other strategies for use in the filler-neck area include the use of one-piece constructions, with the filler-neck directly sealed to the fuel tank and fill-pipe.

Finally, the use of a re-designed gas cap may be necessary to reduce any losses from this source. Current gas caps appear to show some degree of leakage from the sealing area. This is most likely due to either some form of leakage through the pressure relief mechanism contained in the gas cap or due to the flexing of the gas cap under the pressure applied from the final twist of the cap and not creating a proper seal with the o-ring. When tested with a more rigid cap without the pressure relief mechanism, vehicles generally exhibited virtually zero leakage. Although the emission loss from this source may be relatively minor, it appears that improvements to the gas cap are feasible to reduce these losses. These improvements would likely include redesign of the pressure relief mechanism, as well as some modification to the basic structure of the plastic fuel cap.

(b) "Zero" Evaporative Emission Standards. The assessment of these standards is detailed below, through vehicle testing for feasibility assessment and a cost analysis.

Vehicle Testing. The "zero" evaporative emission standard of 0.20 grams per diurnal-plus-hot-soak test has been investigated primarily through two means: testing of a Mitsubishi prototype hybrid-electric vehicle with a sealed, pressurized fuel tank and evaporative system; and investigation of background emissions. The "zero" standard is proposed at a level that would likely allow no more than a few hundredths of a gram per test of fuel vapor emissions, with the other emissions being "background" non-fuel emissions from the vehicle paint, tires, and upholstery.

The Mitsubishi vehicle showed an evaporative emission result of 0.13 grams per test during testing at the ARB's laboratory, and an 0.14 gram per test result during testing at Mitsubishi facilities. This vehicle did not contain the additional intake air filter used in the other ARB testing, so that potential results for this vehicle are likely to be somewhat lower than these test values. Although this vehicle is a prototype, staff believes that it represents achievable levels on vehicles with nearly all-metal evaporative and fuel tank systems (the exception being particular fuel hoses of extremely low permeation).

As part of its assessment of this standard, the ARB staff has performed background testing on electric vehicles and obtained information from vehicle manufacturers regarding background emission levels. The two electric vehicles tested by the ARB, a Honda EV Plus and a Chevrolet S-10 pick-up, showed average diurnal results of 0.094 grams and 0.316 grams, respectively. The Honda EV Plus results support the 0.2 grams per test "zero" standard. The S-10 pick-up was tested at just 100 miles and still contained a "new car" smell, so that it is likely that this vehicle has not achieved stable background emissions. Staff intends to re-test this vehicle to determine if actual emissions are lower than these original values.

In private meetings with the ARB, several manufacturers shared background data from testing conducted. These results varied from 0.10 to 0.22 grams per test, with an average of 0.17 grams per test. In addition, published information (Haskew et al., "Real-Time Non-Fuel Background Emissions," SAE 912373) showed background data ranging from 0.15 to 0.25 grams per day on the first day of the diurnal test. Certain manufacturers have also mentioned data showing levels as high as 0.7 grams per test. The ARB staff is still assessing this data.

In general, the HEV and background data presented suggest that the "zero" evaporative standard would be difficult to meet if all vehicles were required to comply. Average vehicle background levels are quite close to the proposed standard. However, under the current proposal only 20 percent of vehicles are required to comply with these standards. Background emissions are generally expected to be lower for small vehicles due to the smaller size of the emitting areas, such as the tires, upholstery, and paint. Supporting this assumption, two of the smaller vehicles, the Mitsubishi HEV and the Honda EV Plus showed comparatively low evaporative results of 0.13 (includes both fuel and background evaporative emissions) and 0.10 grams, respectively.

For this reason, staff believes that manufacturers can build sufficient numbers of smaller-size, “zero”-standard compliant vehicles to meet the proposed 20 percent requirement. In addition, a manufacturer may choose to use vehicle materials, such as interior trim and body paint, that are non or low HC emitting to reduce total vehicle evaporative emissions.

Cost Analysis. Staff believes that cost estimates for a zero evaporative system would be approximately \$100 to \$300 per “zero” standard vehicle. The main part of this cost is generated by the use of a more robust fuel tank combined with relatively complex sealing and pressurizing mechanisms. In some system designs, for example, tank pressure must be directly measured by pressure transducers, while others require the use of special, high-pressure reservoir tanks to contain refueling vapors. Staff believes that these costs are reasonable preliminary estimates, but may be reduced as manufacturers gain experience in developing, certifying, and producing “zero” evaporative systems.

2. Proposed Refueling Emission Standards. To comply with the current ORVR regulatory requirements, automobile manufacturers are using either a dynamic (liquid) or mechanical seal type ORVR system on motor vehicles. The majority of current vehicles are equipped with dynamic seal systems. On dynamic seal systems, a large variation in certification emission values are observed. While some high emission-performing dynamic seal systems show negligible emissions, other have refueling emissions as high as 0.15 grams per gallon. These higher emitting ORVR systems will need to be refined to comply with the proposed standard. Initially, staff believed it would be necessary for manufacturers to use mechanical seal systems to meet the proposed refueling standard. However, meetings with the manufacturers and a review of certification ORVR emission levels have shown that both the dynamic seal and mechanical seal ORVR systems may be used to comply with the proposed refueling standard.

(a) Dynamic Seal Technology. The dynamic seal ORVR system uses the flow of fuel in the vehicle’s fill-pipe to create a venturi effect which prevents refueling vapors from escaping out of the fill-pipe. Although there are many variations in the design of dynamic seal systems, the major components consist of a modified fill-pipe (the dynamic seal design), an anti-spitback valve, a refueling vapor line from the fuel tank to the canister, and an increased carbon canister capacity. Some systems also incorporate a vapor recirculation line which reduces the vapor generation in the fuel tank by recirculating vapor to the inlet of the fill-pipe, thereby limiting the amount of air being ingested into the system. There are 30 dynamic seal ORVR evaporative/refueling families certified for the 1998 model year with emission levels ranging from 0.004 to 0.146 grams HC per gallon. Staff is still investigating reasons why certain systems perform better than others. For example, systems which incorporate refueling vapor recirculation do not consistently perform better than those systems without vapor recirculation.

The major advantage of dynamic seal systems is that there is little potential for deterioration of the seal. The dynamic seal is formed by both the geometry of the fill-pipe and the flow of liquid fuel. Furthermore, this system relies on fewer components than mechanical seal systems and is easer to incorporate within enhanced evaporative system designs. The disadvantage of dynamic seal systems is that its emission performance may be strongly dependent on nozzle position in the fill-neck. Also, nozzle to nozzle shut-off performance and air entrainment characteristics may affect the dynamic seal system performance.

Currently, the ORVR test procedure only requires refueling with a conventional non-Stage II nozzle, and thus the interaction of the ORVR system and Stage II vapor recovery nozzle during a refueling event is not evaluated by the test procedure. However, in California Stage II nozzles are in use at gasoline-dispensing stations. Manufacturers have recently suggested that Stage II refueling nozzles working in conjunction with ORVR systems may improve refueling vapor capture efficiency by collecting vapors that escape the dynamic seal and, therefore, improving refueling efficiency significantly. Staff will investigate the interaction between the ORVR system and the Stage II nozzles to determine how it impacts emissions.

(b) **Mechanical Seal Technology**. The mechanical seal ORVR system prevents refueling vapors from escaping the fill-pipe by the use of a physical barrier (an elastomeric ring) which seals the refueling nozzle tip when inserted into the fill-pipe. The major components used in the design of the mechanical seal systems are a physical vapor barrier (elastomeric ring), vapor and liquid pressure relief valves, additional refueling vapor lines, and an increased carbon canister capacity. There are only four mechanical seal evaporative/refueling families certified for the 1998 model year. Certification refueling emission levels ranged from 0.00 to 0.02 grams per gallon. All these systems performed well below the current refueling standard and would comply with staff's proposed standard.

The major advantage with mechanical systems is that the vapor capture efficiency of the system is not dependent upon nozzle performance, and the physical seal does not allow air to be ingested into the system. The disadvantage of mechanical systems is the possibility of seal deterioration. Several manufacturers have suggested that there remain some durability concerns with these systems because of the physical contact between the elastomeric seal and the refueling nozzle. The concern is that refueling with damaged nozzles may deteriorate the elastomeric seal. However, staff believes that the restrictor plate, present in most vehicles, should alleviate these concerns because it will prevent the insertion of damaged refueling nozzles. Another disadvantage is that the fuel tank pressure management is more complex with mechanical seal systems than with dynamic seal systems. Failure of pressure management components could result in damage to the system. Therefore, mechanical seal systems require additional components to safeguard the system.

(c) **Cost Analysis**. Currently, some dynamic seal and all mechanical seal ORVR technology comply with the proposed 0.04 grams per gallon refueling standard. The 1998 model year certification data on mechanical seal systems suggest that no changes will be required to meet staff's proposed standards. However, many dynamic seal designs will require modifications to comply with the new proposed standard. Manufacturers have also suggested that significantly changing the refueling standard may require them to forgo dynamic seal designs and implement mechanical seal designs on some vehicle models. Therefore, staff has estimated both the cost of improving current dynamic seal systems to meet the proposed standard and the costs associated with changing technology from dynamic to mechanical seal systems. Of the vehicles that do not currently comply with the proposed standard, staff approximates that 20 to 30 percent of the vehicles will require modifications from a dynamic to mechanical seal while the remaining 70 to 80 percent of the vehicle will undergo only modifications of the dynamic seal.

For this cost analysis, staff used the U.S. E PA's "Final Regulatory Analysis on Refueling Emission Regulations for Light-duty Vehicles and Trucks and Heavy-duty Vehicles," adjusting the costs to 1997 dollars by using the latest Product Price Index for consumer durable goods. Costs were rounded to the nearest $0.05. These cost estimates assume high volume production and are on a per-vehicle basis. Also, these estimates are based on single-tank vehicles. There are two categories used in performing this cost analysis. The first category is hardware costs and are associated with the purchase of components in order to comply with the new requirements. The second category is development costs which are related to system engineering, regulatory compliance, and facility modifications. System engineering costs are associated with the design of a system and the integration of it with other vehicle systems. Regulatory compliance costs are related to recertification of vehicles attributed to changes made to the emission system. Other development costs, such as facility modifications, have already been incurred during the introduction of the ORVR requirements and thus are not included in this analysis.

For improvements to current dynamic seal ORVR systems, staff does not believe that additional hardware components will be needed and therefore, has not allocated additional hardware costs in improving these systems. However, improved designs of the dynamic seal system to reduce refueling losses will be needed, which would incur development costs. Staff has determined that the development costs incurred will be predominantly from systems engineering and regulatory compliance. Based on the United States Environmental Protection Agency analysis, the total costs for improvements of dynamic seal systems are estimated at $0.60 for passenger cars, $0.90 for light-duty trucks under 3750 lbs. LVW, and $1.80 for light-duty trucks from 3751 lbs. LVW to 8,500 lbs. GVW.

System design changes from a dynamic to a mechanical seal system will incur both hardware and development costs. The hardware costs will be the difference between the costs of dynamic and mechanical seal components and are estimated at $7.40 for passenger cars and light-duty trucks. The development costs, associated with system engineering and regulatory compliance are estimated at $1.30 for passenger cars and light-duty trucks under 3751 lbs. LVW, and $1.95 for light-duty trucks from 3751 lbs. LVW to 8,500 lbs. GVW. The total costs associated with changing from a dynamic to a mechanical seal system are estimated at $8.70 for passenger cars and light-duty trucks under 3750 lbs. LVW and $9.35 for light-duty trucks from 3751 lbs. LVW to 8,500 lbs. GVW.

D. REGULATORY ALTERNATIVES TO ZERO EVAPORATIVE EMISSION PROPOSAL

The staff considered a regulatory alternative to the proposed evaporative and refueling standards. Staff considered requiring all vehicles to meet the “zero” evaporative/refueling standard that effectively requires that all fuel evaporative emissions be eliminated. Although the technology is feasible and significant emission reductions can be achieved with this proposal, staff believes that there are only limited technologies that are available and until further development is made in this area, requiring all vehicles to meet the “zero” evaporative standard would be severe. Staff found that no other alternative considered would be more effective in carrying out the purpose for which the regulations were proposed or would be as effective or less burdensome to affected private persons than the proposed regulation.

E. ECONOMIC IMPACT OF EVAPORATIVE EMISSION PROPOSAL

Overall, motor vehicle and parts manufacturers are able to weather the costs of the proposed new standards with no noticeable impacts on their profitability. These manufacturers are mostly located outside California. However, they are generally expected to pass on the costs of new standards to vehicle operators in California. The expected increase in retail prices of motor vehicles is estimated to range from $34 to $95 per vehicle in 2006. Staff believes that California businesses would be able to absorb the costs of the proposed new standards with no significant adverse impacts on their profitability. As a result, staff expects the proposed new standards to impose no significant adverse impacts on California competitiveness, employment, and business status.

1. Legal Requirement. Section 11346.3 of the Government Code requires State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California businesses to compete.

Also, State agencies are required to estimate the cost or savings to any state, local agency and school district in accordance with instructions adopted by the Department of Finance. The estimate shall include any nondiscretionary cost or savings to local agencies and the cost or savings in federal funding to the state.

2. Businesses Affected. Any business involved in manufacturing or purchasing passenger cars, light-duty trucks, medium-duty vehicles, and heavy-duty vehicles can potentially be affected by the proposed new standards. Also affected are businesses which manufacture parts for these vehicles. California accounts for only a small share of total nationwide motor vehicle and parts manufacturing. All motor vehicle manufacturing plants except for one are located outside California. Most motor vehicle parts suppliers also tend to locate in areas close to manufacturing plants to minimize shipping costs and delivery time.

3. Potential Impact on Manufacturers. The proposed new standards are expected to impose additional costs on motor vehicle and parts manufacturers. The staff's cost analysis shows that the total costs of the new standards when they are fully phased in would range from about $58 to $166 million annually. This cost increase would have no noticeable impact on the profitability of affected manufacturers. In 1997, the Big Three auto manufacturers reported about $16.5 billion in profit on sales of over $381 billion.

4. Potential Impact on Vehicle Operators. The potential impact of the proposed new standards on the retail prices of motor vehicles hinges on the ability of manufacturers to pass on the cost increases to vehicle operators. Assuming that manufacturers are able to pass on the entire costs of compliance to vehicle operators, staff estimates the average price increase would range from $34 to $95 per vehicle in 2006. New evaporative emission standards account for $32 to $92 of the price increase per vehicle, while the remainder is due to new refueling emission standards. As the average retail price of a motor vehicle presently exceeds $15,000, the cost increase on average represents less than a one-half percent increase in the cost of new motor vehicles. This is not expected to have a significant impact on California businesses and individuals purchasing motor vehicles.

5. Potential Impact on Business Competitiveness. The proposed new standards would have no significant impact on the ability of California businesses to compete with businesses in other states, as the new standards would have only a minor impact on retail prices of motor vehicles.

6. Potential Impact on Employment. The proposed new standards are not expected to cause a noticeable change in California employment. California accounts for only a small share of motor vehicle and parts manufacturing employment. In addition, most manufacturers are expected to pass on the compliance costs to vehicle operators. The increase in retail prices of new vehicles is estimated to range from $34 to $95 per vehicle in 2006. This cost increase is not expected to impose a significant burden on California businesses and individuals. Thus, it would have no significant impact on California jobs.

7. Potential Impact on Business Creation, Elimination, or Expansion. The proposed new standards would cause no significant change in the status of California businesses. The new standards would potentially result in a small increase in retail prices of new motor vehicles. However, this increase in prices is not expected to change the profitability of California businesses significantly.

8. Potential Fiscal Impact on State and Local Agencies. The proposed new standards are not expected to cause a significant fiscal impact on State or local government agencies, as the increase in purchase cost of new motor vehicles is insignificant compared to the cost of new vehicles.

F. ENVIRONMENTAL IMPACT AND COST-EFFECTIVENESS ANALYSIS

1. Environmental Impact. The preliminary statewide and South Coast Air Basin (SoCAB) air quality benefits projected for the proposed evaporative regulation are shown in Tables III-6 and III-7. Due to certain assumptions that still need to be resolved associated with the "near-zero"/"zero" evaporative standards, such as the quantification of vehicle HC background emissions in the inventory, an estimated range of the emission benefits is given for the evaporative standards in the tables. As shown, preliminary statewide reactive organic gas (ROG) emission benefits of the implementation of both the proposed evaporative and refueling regulations are 8 to 12 tons per day in the 2010 calendar year and 29 to 36 tons per day in the 2020 calendar year. Total ROG emission benefits in SCAB is approximately one-third of the statewide benefits. A brief description of the methodology to generate the air quality benefits is provided below.

Table III-6. Projected Statewide Inventory Air Quality Impacts of the Proposed Evaporative Regulation (Tons ROG per Day)

	2010 CY	2020 CY
"Near-Zero"/"Zero" Evaporative Standards	7 - 10	25 - 32
Proposed Refueling Standards	1.5	4.0
Total ROG Benefits	8 - 12	29 - 36

Table III-7. Projected South Coast Air Basin Inventory Air Quality Impacts of the Proposed Evaporative Regulation (Tons ROG per Day)

	2010 CY	2020 CY
"Near-Zero"/"Zero" Evaporative Standards	2 - 4	8 - 11
Proposed Refueling Standards	0.8	2.1
Total ROG Benefits	3 - 5	10 - 13

(a) Methodology for Determining the Emission Benefits of the Evaporative Proposal. In general, the methodology for estimating the emission benefits of the proposed evaporative standards begin with a determination of the baseline evaporative ROG emissions without implementation of the new evaporative standards. Adjustments of these rates were then made as a result of the implementation of the proposed standards. The baseline evaporative emission rates are determined using the most recent version of the ARB inventory model, EMFACX (to be released in late 1998). The baseline rates were modified to account for the fraction of the fleet that will be zero-emission vehicles and for the proposed phase-in schedule. Other modifications to the base emission rates include temperature and Reid Vapor Pressure correction factors to account for these conditions in the enhanced evaporative test procedure as compared to those in the model. The current diurnal and hot soak emission rates are projected out to the proposed useful life to determine the baseline rates.

The following methodology was performed only for passenger cars in SCAB. Scaling factors were developed in order to project emissions for other vehicle categories and for statewide purposes. This inherently assumes that the other vehicle categories would obtain the same percentage reduction in evaporative emissions as the passenger car category. In addition, for modeling purposes, diurnal emissions (as defined in the regulatory context as evaporative emissions occurring over a 24-hour daily period when the vehicle is parked) is divided into two categories: diurnal and resting losses. For this purpose, diurnal emissions are defined as those evaporative emissions that occur from a parked vehicle when the ambient temperature is rising, while resting losses are those that occur from a parked vehicle when the ambient temperature is constant or decreasing.

Since the diurnal-plus-hot-soak emission standard is defined as the sum of the diurnal and hot soak emissions and the analysis models diurnal and hot soak emissions separately, a determination of the associate reduction of diurnal emissions and the hot soak emissions to the proposed diurnal-plus-hot-soak standards is required. Current certification data on very low-emitting vehicles indicate that hot soak emissions are likely to be reduced considerably more than diurnal emissions. Based upon both a qualitative and quantitative review of such data, it is assumed in this analysis that the hot soak emission rate will likely be one fifth of the diurnal rate.

To determine the emission benefits of the proposed diurnal-plus-hot-soak standards, an iterative process is employed to determine the magnitude of the change necessary in the base rates to reduce the current predicted compliance values down to the standard. Since very little data are available to estimate the in-use performance for enhanced evaporative vehicles, it is assumed that all vehicles will meet the applicable diurnal-plus-hot-soak standards. This assumes that in-use recall, the On-Board Diagnostics II Systems, and the Inspection and Maintenance Program will be effective in maintaining vehicles in compliance with the applicable evaporative standards. ARB analyses have shown that the emissions from these vehicles do not deteriorate. Rather, deterioration occurs because of malperformance, and malperformance increases with time and/or mileage. Therefore, it is assumed that the hot soak and diurnal base emission rates remain flat. For multiple-day diurnal events, slightly different assumptions were used. For planning inventories, a high-temperature series of days are assumed, similar to the enhanced evaporative procedure. Therefore a direct reduction of the emission rates by the ratio of current predicted compliance value and the proposed standard was used rather than the iterative process.

ARB modeling treats resting losses as permeation losses with little dependence upon temperature. Thus, resting losses would tend to be very small compared to diurnal emission increases at elevated temperatures. This analysis assumes that because of their magnitude, a manufacturer will not explicitly need to control resting loss emissions. Therefore, no emission benefits are assigned for the “near-zero” evaporative proposal. However, for the “zero” evaporative proposal, all emissions are available for reduction since the evaporative/refueling system would presumably be more robust, such as "sealed" or pressurized.

For running loss emissions, the methodology employs three emission regimes: "Normals," "Moderates," and "Highs." Similar to diurnal and hot soak emissions, the Normal base emission rates were adjusted downward iteratively to where the emission rates would meet the standard. The Moderates were reduced by the ratio of the proposed running loss standard to the current standard but were not lowered to the proposed standard. For the Normals and the Moderates, it is assumed that in-use recall, the On-Board Diagnostics II Systems, and the Inspection and Maintenance Program will be effective. For Highs, the emission rates were not adjusted. It is assumed that since the vehicle has been poorly maintained and/or tampered with, the owner who is willing to drive the vehicle in such shape is unlikely to be influence by in-use recall, the On-Board Diagnostics II Systems, and the Inspection and Maintenance Program.

(b) **Methodology for Determining the Emission Benefits of the Refueling Proposal.** The methodology for estimating the incremental emission benefits of the "near-zero" refueling standards assumes that current ORVR systems are 95 percent efficient and that the improved ORVR systems will be 99 percent efficient (determined based on percent reduction from the current standards). As discussed earlier, staff will investigate the interaction of the ORVR system and the Stage II vapor recovery nozzle. However, since this relationship is currently being reviewed, for the purposes of this analysis the current ORVR baseline is assumed at 95 percent efficiency.

Since no emission factor has been developed by ARB related to the current or improved ORVR refueling system, the best available information is from the Gasoline Service Station Industry-wide Risk Assessment Guideline (Toxic Committee of the California Air Pollution Control Officers Association, 1997). Both the current and improved refueling systems are assumed to behave similarly to the above tank refueling system (with Stage II control) as described in the aforementioned report.

As the overall control efficiency in the ORVR increases from 95 percent to 99 percent, the refueling losses consequently are lowered. Using information from the Gasoline Service Station Industry-wide Risk Assessment Guideline to establish the baseline refueling losses at 95 percent efficiency, the incremental emission benefit when the improved refueling system increases the control efficiency to 99 percent is estimated to be 0.226 pounds per 1000 gallons. This incremental emission factor is then adjusted by a fuel correction factor because the vapor pressure used in the emission factor is higher than the California Phase II reformulated gasoline. The total vehicle miles traveled for vehicles affected by the proposed refueling regulation in calendar years 2010 and 2020 are estimated using MVEI7G version 1.0c and are used to calculate the fuel consumption. Finally, using the projected fuel consumption and estimated incremental emission factor, the incremental emission benefits are calculated and are shown in Tables III-6 and III-7.

2. Cost-Effectiveness Analysis

For the proposed evaporative standards, staff has estimated a preliminary hardware cost of approximately $15 to $40 per vehicle for the "near-zero" standards and $100 to $300 per vehicle for the "zero" standards. The development costs associated with these modifications have not yet been estimated, although they will likely be only a small portion of the overall costs relative to the hardware costs. Assuming 1.8 million new vehicles are sold per year to which these standards are applicable, the total cost for compliance with the proposed evaporative standards of 80 percent "near-zero" evaporative standard and 20 percent "zero" evaporative standard is $58 to $166 million annually or $158,000 to $454,000 daily. In 2020 when fleet turnover is almost complete, staff has projected the ROG air quality benefits to be 25 to 32 tons per day statewide. Thus, the preliminary cost-effectiveness of the evaporative proposal is $6,300 to $14,200 per ton ROG reduced or $3.20 to $7.10 per pound ROG reduced.

As noted earlier, staff has estimated that approximately 20 to 30 percent of vehicles would require mechanical seal ORVR systems to comply with the proposed refueling standard, with the remaining vehicles requiring only improved design of the dynamic seal system. Although a number of current ORVR systems already comply with the proposed standard, as a conservative estimation staff will assume that all systems will require modifications and include costs associated with them. Assuming 1.7 million new passenger cars and light-duty trucks under 8,501 lbs. GVW are sold per year to which the refueling standard is applicable, and using the estimated percentage of mechanical and dynamic systems required to comply with the standard noted above, total cost ranges from $4.0 to $5.4 million annually or $11,000 to $15,000 daily. In 2020, staff has projected the ROG air quality benefits to be approximately 4 tons per day statewide. Thus, the preliminary cost-effectiveness of the refueling proposal is $2,800 to $3,700 per ton ROG reduced or $1.40 to $1.80 per pound ROG reduced.

IV. PROPOSED AMENDMENTS TO CALIFORNIA'S MOTOR VEHICLE CERTIFICATION, ASSEMBLY-LINE AND IN-USE TEST REQUIREMENTS ("CAP 2000")

A. BACKGROUND

The California Health and Safety Code requires a manufacturer to demonstrate that its vehicles meet the applicable emission standards in three ways: at the time of certification, as the vehicles are produced on the assembly-line, and in actual customer use. These programs have been in place for many years. However, changing emission standards and advancements in automotive technology have reduced the effectiveness of the certification and assembly-line requirements. In 1995, the U.S. EPA, ARB and the automobile manufacturers signed a Statement of Principles that states:

> "... the Signatories commit to working together to achieve regulatory streamlining of light-duty vehicle compliance programs, including reduction of process time and test complexity, with the goal of more optimal resources spent by both government and industry to better focus on in-use compliance with emission standards."

Since then, staff has been working with U.S. EPA and the automobile industry to develop a streamlined motor vehicle certification process coupled with an enhanced in-use compliance program (called "Compliance Assurance Program" or "CAP 2000").

The goal of EPA and ARB in CAP 2000 is to redirect manufacturer and government efforts toward in-use compliance, which would provide greater assurance that vehicles are actually complying with the standards in-use. The amendments being proposed in this rulemaking divert the significant resources presently devoted to motor vehicle certification and reallocates a portion of them towards in-use compliance. Reducing the regulatory burden during certification would provide manufacturers with more control over their production timing, which would provide significant savings, while the enhanced in-use test programs would provide more air quality protection. This proposal will be effective with the 2001 model year although manufacturers may certify their 2000 model year vehicles using the CAP 2000 framework as adopted by the Board. The following is a brief description of the current certification and in-use programs. Part B describes the amendments being proposed under CAP 2000.

Pre-Production Certification Procedure. In order to certify a vehicle for sale in California, a manufacturer must submit test data to the Executive Officer prior to the start of production that demonstrates the vehicle meets the applicable standards. This requires the use of procedures that enable the manufacturer to predict the anticipated emissions deterioration (called the "deterioration factor") of the vehicle in-use using pre-production, developmental vehicles. Once the deterioration factor is established, low mileage "emission-data" vehicles are tested and the emission results are adjusted using the deterioration factor to determine whether the vehicle meets the emission standards throughout its useful life. A manufacturer must provide this information for each "engine family," which is a group of vehicles having engines and emission control systems with similar operational and emission characteristics, in order to be granted an Executive Order (EO) approving vehicles in the engine family for sale in California.

Assembly-Line Production Procedure. Once an EO has been granted, Section 2062, Title 13, California Code of Regulations (CCR) requires the manufacturer to emission test a small portion of actual production vehicles in each engine family as they leave the assembly-line to ensure that the emissions of actual production vehicles also comply. This is called "quality-audit testing." Vehicles that do not comply with the standards are required to be repaired or the manufacturer could be subject to penalties.

Post-Production In-Use Compliance Procedure. The ARB procures late-model vehicles from their owners for emission testing to determine whether vehicles that have been properly maintained and used comply with the standards in actual use. If the ARB test data or emission control components are identified that demonstrate an engine family does not comply, the manufacturer must either submit a plan to remedy the non-conformity at the manufacturer's expense or be required to recall the vehicles. In either case, penalties could be assessed. The ARB in-use test program protects air quality because it not only forces the repair of non-complying vehicles but also acts as a substantial deterrent to manufacturers that wish to avoid the expense (both in cost and in lost customer satisfaction) associated with a recall.

The U.S. EPA administers essentially the same requirements under the Clean Air Act but because California is allowed to set its own emission control program, there are differences between the two programs. The next section describes the proposed "CAP 2000" program and how the proposed amendments affect California's certification and in-use programs.

B. SUMMARY OF PROPOSED MODIFICATIONS

In the late summer of 1998, it is expected that EPA will release its Notice of Proposed Rulemaking (NPRM) which provides a complete description of the proposed CAP 2000 program. Because EPA and ARB have agreed to harmonize to the greatest extent possible, this section will briefly summarize the key components of CAP 2000 and will focus mainly on how the proposed CAP 2000 amendments will affect California's programs. The reader is directed to the federal docket, which contains a complete description of the proposed federal amendments as well as the complete federal regulatory text. Due to the technical nature of the amendments, a detailed description of the proposed amendments to the California regulatory text is contained in Appendix B of this Preliminary Staff Report.

1. Amendments to Pre-Production Certification Procedures. The proposed CAP 2000 program significantly reduces the emission testing and reporting requirements for certification and provides manufacturers with more control over roll out of their product lines. Currently manufacturers are required to establish emission deterioration data on every engine family using a low speed, high mileage test procedure (called the “AMA” cycle) or by approved bench aging the emission control components and then testing the vehicle with the fully aged components. Once the deterioration factor is determined the manufacturer must test two emission-data vehicles in every engine family. This is a costly and time-consuming process and may not provide a realistic appraisal of the ability of the vehicle to comply. Under CAP 2000, a manufacturer will be able to develop its own durability demonstration (with pre-approval by the Executive Officer) and apply it to several engine families that have been grouped into a broad category of vehicles called “durability groups” that exhibit similar deterioration characteristics. The durability demonstrations that manufacturers would be using are expected to provide a more realistic appraisal of the emission deterioration of the vehicles. Within each durability group, there are several “test groups” (similar to the current engine family designation) that are based on the emission standards to which a vehicle is certified. Manufacturers would then select one “worst case” vehicle from each test group to emission test rather than the two required under the current program. This reduction in testing would result in more than a 75% reduction in the number of durability demonstrations now required and a 50% reduction in the number of emission data vehicles tested.

In addition, CAP 2000 would provide more flexibility in the information required for certification. Under the current program, a manufacturer is required to submit all of the certification data prior to issuance of the EO. Under CAP 2000, only the most essential certification information (e.g., that the vehicle meets the standards) would be required before EO approval with the remainder (e.g., test parameters, or detailed maintenance instructions) being required prior to the end of the model year. Eliminating the requirement that all documentation must be submitted prior to EO approval means that production plans will not be held up for non-essential pieces of information.

2. Amendments to Assembly-Line Production Testing. Under the current California program, manufacturers are required to perform functional tests on every vehicle component during the assembly process and then conduct a full emission test for a portion of the vehicles (approximately 2%) at the end of the assembly-line. The proposed amendments to CAP 2000 would eliminate the 2% end-of-line emission tests because the proposed manufacturer-conducted in-use testing discussed in paragraph B.3 below is more likely to ensure that manufacturers utilize durable emission control systems to prevent a potential recall. Additionally, any misbuilds or any parts that are not operating within design parameters would be detected by OBD II system checks conducted during the functional test on the assembly line.

When the quality audit testing was first instituted, vehicles utilized carbureted fuel systems and most emission control components were operated mechanically rather than electronically. The operating parameters varied much more than is found in today’s vehicles, where sophisticated electronic controls achieve very narrow operating regions. In the past, the much larger variability of components made it necessary to emission test a portion of the assembly-line vehicles to ensure that each vehicle was operating properly after assembly and could meet the applicable emission standards. In order to meet today’s low emission standards, however, vehicles utilize sophisticated electronic controls that exhibit little variability and are self tuning for optimum emission performance.

In addition, emission testing of a vehicle at zero miles is not a good indicator of the ability of a vehicle to meet today's low emission standards. The presence of manufacturing oils in the engine and other components will likely increase the emissions of a vehicle as they burn off when the engine is first started. There could also be increased positive crankcase ventilation valve emissions until the piston rings have had a chance to properly seat. With today's low standards, there is very little margin for error and these factors could affect the emission results while not being fully representative of the vehicle's ability to meet the standards over time.

Finally, because there has been very few failing engine families reported from assembly-line testing in recent years, and because the 100% functional test requirement is still in effect, staff believes that the quality audit test is no longer cost-effective and that the end-of-line testing resources would be better utilized on the in-use testing required by CAP 2000. Therefore staff is proposing that the 2% quality audit requirement be eliminated.

The federal government has a similar requirement, Selective Enforcement Audit, that it is also proposing to eliminate in favor of the manufacturer-conducted in-use test requirements discussed below.

3. Implementation of Manufacturer-Conducted In-Use Testing Requirements. Under current California regulations, the ARB procures and tests customer vehicles that have been properly maintained and used. Based on a number of predictive tools (certification data that is too close to the standard at the time of certification, indications of failures from the on-board diagnostic systems, Smog Check results, warranty reports that indicate a problem, or a previously failing engine family), ARB staff targets engine families that may not pass the standards. The engine families identified for testing cover about 15% of the total annual vehicle production for California. The test program has been very successful and will continue to operate under CAP 2000.

The amendments being proposed in this rulemaking would additionally require manufacturers to procure and test customer vehicles both at 10,000 miles, at 50,000 miles and one vehicle from every test group at a minimum of 75,000 miles. Manufacturers are required to test vehicles "as received" (rather than screening to exclude vehicles that have not been properly maintained and used) from every test group. If the vehicles tested do not meet the applicable emission requirements, a manufacturer must then conduct a subsequent test program on properly maintained and used vehicles to determine whether remedial action is required. The information received from the manufacturer-conducted testing would verify the efficacy of the manufacturer's durability demonstration required during the certification process and would also be used by the ARB to target potential problem test groups for evaluation.

Aside from some requirements that are specific to California (e.g., evaporative emission requirements, and zero-emission and hybrid electric vehicle testing), the U.S. EPA and California in-use test program requirements are essentially the same.

C. REGULATORY ALTERNATIVES

Because most of the certification streamlining effort was cooperatively developed in conjunction with U.S. EPA and industry, most of the proposed regulatory amendments are a result of examination of all the regulatory alternatives available to government and industry. Throughout the process, the goal of ARB staff was to eliminate requirements that are no longer cost-effective, reduce unnecessary testing, harmonize where possible with U.S. EPA while maintaining the stringency of the California programs. The following alternatives were considered by staff.

1. Do not amend current California regulations. Staff believes that keeping the current program would not provide the same level of protection that is anticipated under CAP 2000. For the reasons stated earlier in this staff report, staff believes that current certification and assembly-line test programs have become less effective and do not provide the degree of protection that would be afforded by a comprehensive in-use compliance program. Unnecessary certification testing and paperwork often delay and add significant cost to a manufacturer's production costs but do not likely provide the same degree of protection that would be provided by an in-use test program.

2. Adopt a California-only program. The ARB, EPA and automobile industry have been working together for over two years to develop a streamlined certification program coupled with an enhanced in-use test program that is harmonized to the greatest extent possible between California and EPA. During the process, the ARB worked diligently to protect the stringency of our own programs within the framework of the CAP 2000 proposal. The program being proposed in this rulemaking is the result of these extensive negotiations. The ARB staff believes that it would not be cost-effective or in the best interests of California to propose a separate program that would add undue regulatory burden on manufacturers with essentially little, if any, added benefit. The program being proposed in this rulemaking addresses California's concerns and essentially provides more protection than is present under the current programs.

3. Adopt the federal regulations. The proposal before the Board in this rulemaking is essentially equivalent to the federal program with minor exceptions for California-only programs (e.g., emission testing at 50°F, zero-emission and hybrid-electric vehicle testing, evaporative test requirements). Staff believes that the proposed harmonization with the proposed federal amendments relieves manufacturers of unnecessary regulatory burden while the proposed manufacturer-conducted in-use test requirements would provide an even greater degree of protection than under the current in-use compliance program.

D. ECONOMIC IMPACT ANALYSIS

The proposed regulatory amendments bring California's motor vehicle certification program to a large extent into accord with the federal program. The convergence of the California and federal programs would reduce compliance burdens by reducing the requirements for certification and assembly-line testing. However, the amendments would add the requirement for manufacturer-conducted in-use testing. Although an enhanced in-use test program would be more expensive, the added costs are more than offset by the cost savings associated with the reduction of requirements for certification and assembly-line testing. Overall, staff believes the proposed amendments would result in savings to automobile manufacturers. To the extent that these cost savings are passed on to consumers, California businesses and consumers would benefit. Therefore, staff anticipates that the proposed amendments would cause no noticeable adverse impact in California employment, business status, and competitiveness.

1. Legal requirement. Sections 11346.3 and 11346.54 of the Government Code require State agencies to assess the potential for adverse economic impacts on California business enterprises and individuals when proposing to adopt or amend any administrative regulation. The assessment shall include a consideration of the impact of the proposed regulation on California jobs, business expansion, elimination, or creation, and the ability of California business to compete.

State agencies are required to estimate the cost or savings to any state or local agency, and school districts. The estimate is to include any nondiscretionary cost or savings to local agencies and the cost or savings in federal funding to the state.

2. Affected businesses. Any business involved in manufacturing passenger cars, light-duty trucks and medium-duty vehicles would be affected by the proposed federal and state certification and in-use testing requirements. The proposed amendments would have no adverse impact on California businesses and individuals purchasing motor vehicles, especially since the amendments are expected to result in cost savings to motor vehicle manufacturers. All auto manufacturing plants except one are located outside California.

3. Estimated cost to manufacturers. In the Notice of Proposed Rulemaking released by the EPA later this year, the EPA will provide a detailed estimate of the cost savings associated with the proposed federal amendments. In the draft NPRM sent to the federal Office of Management and Budget, EPA concludes that the proposed CAP 2000 amendments would result in substantial savings to manufacturers, potentially in excess of $55 million per year. California adoption of these requirements would increase cost savings to auto manufacturers by $30 million due in large part to the elimination of 2% quality audit testing.

4. Estimated cost of CAP 2000. Staff followed the U.S. EPA cost analysis in developing the costs and potential savings due to CAP 2000. Because the NPRM has not yet been published, EPA has requested that ARB not release the details of our analysis. The full staff analysis will be available in the final staff report which is scheduled for release in September of this year. However, the following is a summary of the costs and savings attributable to CAP 2000 for California-only and 50 state engine families:

	Minimum (millions)	Maximum (millions)
Net Information Savings	$ 27.3	$ 27.3
Net Durability Savings	22.4	37.2
Net Emission Vehicle Savings	1.6	2.6
Elimination of 2% Quality Audit Testing	26.6	47.5
	77.9	114.6
Cost of New In-Use Verification Program	$ 1.6	$ 7.8
Cost of In-Use Confirmatory Program	0	.3
	(1.6)	(8.1)
TOTAL CAP 2000 SAVINGS	$ 76.3	$ 106.5

5. Potential impacts on California business. The proposed amendments are most likely to have beneficial impacts on California businesses and individuals. The amendments are intended to streamline the emission testing and reporting requirements for new vehicles. The amendments are expected to reduce substantially the requirements for certification and assembly-line testing while increasing the requirements for in-use testing. The streamlining of the emission testing programs is expected to improve its effectiveness greatly and result in cost savings to auto manufacturers. To the extent the cost savings are passed on to consumers, California businesses and individuals purchasing motor vehicles would benefit.

6. Potential impact on business competitiveness. The proposed amendments would have no adverse impact on the ability of California businesses to compete with businesses in other states. The amendments would bring the federal and California programs into accord, resulting in cost savings to auto manufacturers and potentially to California businesses and individuals.

7. Potential impact on employment. The proposed amendments are not expected to cause a noticeable change in California employment because only one automobile manufacturing plant is located in California. However, the proposed amendments are not expected to affect the ability of this manufacturer to produce vehicles especially since the proposed amendments are expected to result in cost savings. There could be an increase in California employment because manufacturers located outside of California would be required to conduct their in-use testing using contract laboratories located in California.

8. Potential impact on business creation, elimination or expansion. Other than the increase in the use of contract laboratories to conduct in-use testing, the proposed amendments are not expected to affect business creation, elimination or expansion.

9. Potential costs to local and state agencies. The proposed amendments are not expected to result in an increase in costs for state and local agencies. Because the focus would be shifted from certification to in-use, it is expected that there would be the same adjustment in the focus of staff of the ARB. Thus, there would be no net gain or loss of person years from the implementation of CAP 2000.

E. ENVIRONMENTAL IMPACT ANALYSIS

The proposed CAP 2000 amendments would not be expected to result in any increase in emissions and thus would not be expected to adversely impact the environment. Rather, it is anticipated that the implementation of the manufacturer-conducted in-use test program would likely decrease emissions because vehicles would be more likely to comply with the standards in-use which would provide greater protection of our air quality.